AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

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1. SUBJECT CLASSIFICATION

A. PRIMARY: Serials — AF00-0130-0000

B. SECONDARY: Plant production--Cereals--Millets

2. TITLE AND SUBTITLE

Improvement of pearl millet; annual report, 1977/1978

3. AUTHOR(S)

(101) Kan.State Univ. Dept. of Agronomy

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1978	119p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

Kan.State

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

(Research summary)

9. ABSTRACT

10. CONTROL NUMBER

PN-AAG-486

11. PRICE OF DOCUMENT

12. DESCRIPTORS

Millet
Nutritive value
Crop diseases and pests

13. PROJECT NUMBER

931104000

14. CONTRACT NUMBER

AID/ta-C-1458

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

IMPROVEMENT OF PEARL MILLET

CONTRACT: AID/ta-C-1458
PROJECT: 931-1040

PROJECT OFFICE DS/AGR/FCP

First annual report for the period October 1977 through September 1978 submitted to the Agency for International Development by Kansas State University, Manhattan, Kansas.

Richard L. Vanderlip
Principal Investigator
Professor of Agronomy
Kansas State University

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Published with the support of Development Support Bureau, Office of Agriculture, Agency for International Development, Department of State, Washington, D.C. 20523, John T. Yohe, Senior Program Manager.

Issued by Departments of Agronomy and Grain Science & Industry, and Fort Hays Branch Experiment Station, Kansas State University of Agriculture and Applied Science. Available to all individuals without discrimination on the basis of race, color, national origin, sex, or religion.

ANNUAL REPORT

October 1977 - September 1978

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Executive Summary

This section contains abstracts of research results in support of the four research objectives of the contract plus a brief narrative of other project activities. More detailed information is provided in other sections of the report.

Research Results. Detailed results see Section VI, page 40.

Objective 1. "Accelerate improvement in pearl millet yield by creating widely adapted high yielding populations and synthetic varieties and investigate possibilities of creating inbred lines and hybrids for use in developing countries."

Pearl Millet Breeding
[*Pennisetum americanum* (L.) K. Schum.]

W. D. Stegmeier

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Pearl millet breeding and research was started in 1971 at the Fort Hays Branch Experiment Station. The work has progressed through the initial screening of materials available from the Southern Regional Plant Introduction Station, Experiment, Georgia and the World Pearl Millet Collection to the present stages of development of several populations, composites, and dwarf, early-maturing hybrids and inbred lines. In order to obtain breeding populations from the introduced materials, it was necessary to make extensive use of varieties from Ghana and Uganda to obtain earliness and increased seed size and forage inbreds from Georgia to provide dwarfness and the A_1B_1 and A_2B_2 cytoplasmic male-sterility and fertility maintainer systems. Therefore, the germplasm base of the breeding population is restricted and crossing and backcrossing to both the original and new introductions will be necessary to obtain additional variability. Hays Millet Population (HMP) 550 and HMP1700 have been advanced, respectively, to the Cycle 2 progeny testing phase and the Cycle 1 recombination generation. Development of lines to be used as parents of grain type F_1 hybrids continues to show promise. Several dwarf millet hybrids with maturity requirements similar to the sorghum checks produced yields, plant heights, and lodging scores comparable to hybrid grain sorghum.

Yield and Heterosis Studies of Pearl Millet
[*Pennisetum americanum* (L.) K. Schum.]

J. C. Palmer, H. A. Praeger, Jr. and W. G. Stegmeier

(Page 48)

Pearl millet [*Pennisetum americanum* (L.) K. Schum.] often is characterized by low yields, excessive height, and small seed size. In the first experiment, selected millet hybrids were grown in field

plots and their performance compared to that of commercially available sorghum hybrids of the same maturity. In the second experiment, heterosis was studied among certain parental lines of pearl millet and their F_1 offspring. In both experiments, attention was focused on yield, seed weight, plant height, and head number per unit area.

Results indicate that millet hybrids are capable of yielding as well as sorghum hybrids under the same conditions. The highest yielding pearl millet hybrids are still typified by excessive height. Heterosis was demonstrated in a number of F_1 millet crosses, indicating that hybrid seed production is one of the better approaches to the problem of increasing yields. Very large seeded types were not found, though some hybrids did produce much larger seed than others.

Objective 2. "Determine factors related to and genetic variability in seed and seedling vigor, water use, drought resistance, and herbicide susceptibility of pearl millet."

Herbicide Susceptibility of Pearl Millet [*Pennisetum americanum* (L.) K. Schum.]

W. B. Ndahi, O. G. Russ, and M. C. Lundquist

(Page 56)

In 1977 and 1978, herbicides commonly used in sorghum production were evaluated on pearl millet at Manhattan and Minneola, Kansas. In 1977 as a result of chinch bug attack at Manhattan and drought at Minneola, there were no treatment differences observed. In 1978 at Manhattan, marked differences in treatments were observed. Millet tolerated the following herbicides: Atrazine, Cyanazine, Modown, Propazine, and Igran. Bexton alone or with any other herbicide did not allow emergence, but replanting Bexton-treated plots three weeks after the first planting gave some yield. Eradicane killed all the millet on both first planting and the replanting.

Seed Vigor Measurements and Their Use in Predicting Field Establishment of Grain Pearl Millet [*Pennisetum americanum* (L.) K. Schum.]

G. J. Mwageni and R. L. Vanderlip

(Page 59)

Seed vigor is one of the problems that limits pearl millet production because it directly affects field establishment. Laboratory and field tests were conducted in 1977 and 1978 to investigate the degree to which laboratory tests could predict field establishment of pearl millet. Laboratory tests included standard germination,

electrical conductivity of soaked seeds, and stress tests of soaking the seeds in ammonium chloride solution, soaking seeds in sodium hydroxide solution, artificially aging at high temperature and relative humidity, and soil cold testing. In 1977, 20 varieties were used while in 1978 a different set of 30 varieties were used.

Germination percentages from the stress tests were lower than those from standard germination as seeds of low vigor were killed after being subjected to the adverse treatments while vigorous seeds remained relatively unaffected.

Criteria used to evaluate vigor tests were: correlation with field establishment, and ranking millet varieties according to field performance.

These criteria suggest that all laboratory tests used except the electrical conductivity following 30 minute soaking were able to screen vigorous from non-vigorous seeds. Soaking the millet seeds in 5% sodium hydroxide solution for 2 minutes prior to normal germination seemed to be the best vigor test although NH_4Cl, accelerated aging, and standard germination treatments were significantly similar in ranking the varieties.

The Effect of Seed Size and Density on Field Emergence and Yield of Pearl Millet [*Pennisetum americanum* (L.) K. Schum.]

J. C. Gardner and R. L. Vanderlip

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This study was conducted to determine whether seed size and seed density had an effect on field emergence, stand establishment and grain yield. Five pearl millet varieties were utilized, with eight treatments per variety. The seeds were separated into four seed sizes, two density fractions, seeds from the original seed lot soaked in sucrose like those separated by density and the original seed lot. The data were collected from two planting dates at two locations. Medium to large seeds and high density seeds improved both field emergence and yield.

Drought Resistance Screening of Pearl Millet [*Pennisetum americanum* (L.) K. Schum.]

P. Singh and E. T. Kanemasu

(Page 72)

Pearl millet is primarily grown in areas and in periods of low precipitation. It is recognized as one of the most drought resistant cereals. Its drought resistant characteristics are not well known

or documented. This study investigates the water use and leaf temperatures of pearl millet. The data from one growing season indicates that the genotypes having the highest leaf temperatures produce the greatest grain yield.

Objective 3. "Determine the nutritional quality and digestibility of pearl millet grain by analyzing protein in germplasm introductions and breeding materials and determining magnitudes of variation in lysine content among and within populations and varieties. Determine the characteristics and digestibility of pearl millet protein and carbohydrates."

Nutrient Content of Pearl Millet
[*Pennisetum americanum* (L.) K. Schum.]

E. Varriano-Marston, R. C. Hoseney and Y. F. Yeh Chung
(Page 85)

Crude protein, ash, mineral content, amino acid analysis, and riboflavin content were run on 4 bulk populations and 17 HMP550 lines. The results indicated that there was little variability among cultivars with respect to the factors measured.

Pearl Millet Proteins
[*Pennisetum americanum* (L.) K. Schum.]

B. Mason and R. C. Hoseney

(Page 95)

The classification of cereal proteins according to their solubility properties determines why certain cultivars contain more nutritious protein. The alcohol soluble prolamines are generally deficient in lysine while the saline soluble and alcohol insoluble are comparatively rich in this amino acid. The amino acid composition of each solubility class has been fairly uniform among the cereals studied. It is not known whether the proteins of pearl millet will follow a similar pattern. Work is continuing to identify a protein fractionation procedure which adequately solubilizes pearl millet protein and yields consistent and distinct protein fractions.

Pearl Millet Starch
[*Pennisetum americanum* (L.) K. Schum.]

A. Beleia and E. Varriano-Marston

(Page 96)

Starch comprises the major carbohydrate of pearl millet; the average content ranges from 60-65%. The properties studied to date

include starch granule size, shape, gelatinization range, and pasting properties of washed starch. The study has been expanded to include water binding capacity, iodine affinities, swelling and solubility patterns, amylose-amylopectin ratios, intrinsic viscosity, and susceptibility to enzyme attack.

Grain Quality Tests to Predict End-Use Properties
[*Pennisetum americanum* (L.) K. Schum.]

A. de Francisco and R. C. Hoseney

(Page 100)

Evaluation of cereal grains has shown the best measure of the functional quality of grain is its ability to produce a product that is acceptable to the consumer. As pearl millet is not a food crop in the U.S., it is difficult to judge consumer acceptability. We are working to develop simple tests that characterize the cooking characteristics of various cultivars. Examination of the simple tests of water absorption, hardness and alkali disintegration are being studied to differentiate pearl millet cultivars. Standardized tests for making chapaties and other products from pearl millet are being developed.

Animal Feeding Studies
[*Pennisetum americanum* (L.) K. Schum.]

S. Dassenko and B. Fryer

(Page 101)

The study of pearl millet quality requires an evaluation of the nutritional quality of the grain with respect to living biological systems. Weanling rats were fed for a 28 day period on 10% protein diets which were adequate in all other nutrients. Protein efficiency ratios, protein digestibility and calorie digestibility of five diets were determined. The sources of protein were casein, raw whole wheat, raw millet, wheat chapaties and millet chapaties. When weight gain was adjusted to feed intake, rats on casein diet gained more than rats on any cereal diet. Of the cereal diets tested, rats gained more on raw millet than raw wheat. Cooking millet in the form of chapaties resulted in a significant decrease in weight gain compared to the raw product.

Objective 4. "Determine the storage stability of pearl millet grain and millet meal by determining the factors contributing to grain losses during storage and determining the factors contributing to the development of rancidity in millet meal."

Characterization of Lipids in Pearl Millet [*Pennisetum americanum* (L.) K. Schum.]

C. Lai and E. Varriano-Marston

(Page 103)

Free and bound lipids and fatty acids were determined for four populations and 18 HMP 550 S_1 lines. The free lipid content ranged from 5.87% to 7.08%; bound lipids ranged from 0.57% to 0.90%. Non-polar lipids were tentatively identified as sterol esters, triglycerides, diglycerides, free fatty acids and partial glycerides. Monogalactosyl glycerides, phosphatidyl choline and lysolecithin were tentatively identified as components of the bound, polar lipid fraction.

Quality Deterioration During Storage [*Pennisetum americanum* (L.) K. Schum.]

C. Lai

(Page 106)

The HMP 550 bulk population of pearl millet was ground and the whole meal stored in cotton bags under the following conditions: 19°C, 58% relative humidity, 27°C, 64% RH and 42°C, 75% RH. After designated storage periods tests were conducted to determine titratable acidity, moisture content, mold counts and organoleptic (sniff) tests using a trained panel. The total titratable acidity increased rapidly for millet stored at high temperatures and relative humidity during the first 108 hours of storage compared to millet stored at lower temperatures and relative humidity. The organoleptic evaluation of stored millet meal indicated that high temperature and humidity resulted in a decrease in the time necessary for detection of off-odors. Organoleptic evaluation appears to be a more sensitive measure of deteriorative changes during storage than total titratable acidity.

Field Fungi in Pearl Millet [*Pennisetum americanum* (L.) K. Schum.]

R. Burroughs

(Page 109)

The field fungi invading pearl millet at harvest were determined by plating 100 surface disinfected kernels on malt agar. Fungi were identified after 6-7 days incubation at room temperature. The predominant fungus was *Alternaria* with smaller percentage of kernels invaded by *Fusarium* and *Claclosporium*. Also identified on the millet kernels were the genera *Curvularia*, *Helminthosporium*, *Penicillum*, *Phoma* and

Rhizopus. The principal field fungi found are of the same genera, and approximately the same percentages, as found in grain sorghum grown in Kansas.

Initial Screening of Pearl Millet to Determine Insect Susceptibility
[*Pennisetum americanum* (L.) K. Schum.]

D. Kossou and J. Pedersen

(Page 111)

A bulk population of pearl millet grown in Kansas was used to determine the susceptibility of infestation by certain species of stored-product insects. Fifteen of the major insect pests species which attack cereal grains were used in a "no-choice" screening test. Twenty-five gram samples of millet at 13.5% moisture content were infested with either 30 adult, 30 newly emerged larvae or 50 eggs, depending on species of insect. Infested millet samples were stored in small glass jars in a rearing room maintained at 27°C and 65% relative humidity for a period of 6-8 weeks. At the end of the exposure period each sample was examined for number of insects, loss of seed weight and weight of frass (excrement, dust, etc.). Rice and maize weevils produced the greatest number of insects per sample (22 and 19 fold increases) and were responsible for the greatest loss (44 and 43%). Granary weevils, lesser grain borers, sawtoothed grain beetles and cigarette beetles had 5-6 fold increases and were responsible for 5-18% weight loss. The red flour beetle had only a 4-fold increase but caused a 9% weight loss.

Planning Meetings Five IN-PROGRESS-REVIEWS were attended by the principal researchers and graduate students working with pearl millet. During these meetings plans for the research projects were coordinated among the various personnel and evaluations on the progress of the research were made. Minutes of these reviews were provided AID and the decision making personnel at KSU and are in Section II, page 10.

International Travel There were four international travel coordination programs during the year. Drs. Hoseney and Marston were on two trips, one to England, Germany, Sudan, and India; the other to Canada to participate in the International Cereal and Bread Congress. Drs. Vanderlip, Praeger, and Stegmeier were in Nigeria, Niger, Upper Volta, and Senegal in Africa; and in India observing millet as it is grown by farmers in the LDC's and coordinating with millet researchers of ICRISAT and the national programs. Dr. Kanemasu visited England, India, Malaysia, and the Philippines coordinating his drought resistance selection work. Copies of the trip reports are in Section III, page 17. Contacts were established with one hundred thirty-six pearl millet research personnel in twelve countries during the year. A list of these personnel is in Section IV, page 30.

Publicity Dr. Vanderlip presented a seminar to the faculty and agronomy graduate students on the implementation of this project. News releases were prepared and sent to all Kansas newspapers. A taped interview for radio was distributed to all Kansas radio stations. The fall field day at the Agronomy Farm, Manhattan, Kansas and Ft. Hays Branch Experiment Station, Hays, Kansas included pearl millet as one of the stops on the tour.

Personnel. There are seven principal research personnel assigned to this project. Other members of faculty and experiment station personnel provided input to the program. They were assisted by seventeen graduate students, technicians and specialists. Nine undergraduate students who work for the project are employed on an hourly basis. A list of the personnel is in Section V, page 38.

Budget The original contract was approved as a three year program and funded for the first two years. Later the program was funded for three years in the amount of $770,000.00. The program utilized $160,952.00 the first year. The remaining funds will be reprogrammed for effective utilization during the remainder of the contract. The financial statement is in Section VII, page 115.

General The winter nursery program with the Corozal Sub-Station of the Puerto Rico Agricultural Experiment Station provides a second generation of germplasm for the breeding program. Request for APHIS permits for the breeding program and for import of grain for the Grain Science program have been initiated.

II. Planning Meetings

Committee Meeting - Improvement of Pearl Millet

23 January 1978, Room 106 Waters, KSU

Personnel attending:

Dr. R. L. Vanderlip, Agronomy - KSU
Dr. T. L. Harvey, Entomology - Ft. Hays Exp. Sta.
Dr. R. C. Hoseney, Grain Science - KSU
Dr. E. T. Kanemasu, Evapotranspiration Lab - KSU
Dr. E. V. Marston, Grain Science - KSU
Dr. H. A. Praeger, Agronomy - KSU
Mr. W. D. Stegmeier, Plant Breeder - Ft. Hays Exp. Sta.

Dr. Vanderlip, chairman, called the meeting to order 1315 hours.

1. Discussion concerning the reports that are required for this project.

   a. Quarterly report is a financial report. This will be prepared by Al Praeger with the assistance of Gil Dodge, Kans. Agri. Exp. Sta. accountant. There is no requirement for input from the members of the committee.

   b. Semi-annual Report, the first one is due April, requires input from all members of the committee. Mr. Byergo, Crops Division, AID, is sending a copy of a semi-annual report so we will have an idea of what format to use that is considered adequate for the project. It is expected that the report will be detailed and should include not only what has been accomplished but describe future plans and projects.

2. Discussion of scheduling future meetings of the committee. It was decided to meet every six weeks. The next meeting will be 21 March at 1300 hours, Room 106 Waters Hall, KSU.

3. Discussion of seed source and the amount required for the various projects was held. The requirements for each project must be known and presented at the next meeting so the appropriate plantings can be made for grain production.

4. A copy of the evaluation report for the project was given each member. The evaluation was discussed on how we were to achieve the objectives.

5. International travel was discussed. Tentatively, Dr. Hoseney and Dr. Marston plan to visit ICRISAT and North African countries in late spring or early summer. Drs. Vanderlip, Praeger, and Stegmeier plan visits to ICRISAT and North African countries in late August and early September. Dr. Kanemasu prefers late September for his visits. Dr. Harvey has no current plans for international travel.

   Al Praeger is to find the answers to the following questions concerning international travel.

   a. Contacts that have to be made, and when this has to be accomplished.

b. Visa requirements for the various countries to be visited, i.e. India, Nigeria, Niger, Sudan, Senegal, Upper Volta, England, France, Italy, and W. Germany.

c. Immunizations required? Will Irwin Army Hospital, Ft. Riley, provide the immunizations at no charge?

d. Passport applications for those requiring a passport should be initiated early, recommend like now.

e. Procedure to obtain advance per diem.

6. Al Praeger is to obtain a list of Developing Countries from the International Agriculture office so we can identify the international students of agronomy, Evapotranspiration Laboratory and Grain Science who can be considered to be trained in this project to accomplish that objective.

7. Dr. Frank Bidinger, Plant Physiologist, ICRISAT, is on home leave and plans to visit KSU. Dr. Vanderlip will try to schedule his visit so all can have an opportunity to coordinate projects.

8. For the next meeting:

a. Have a draft of your contribution to the semi-annual report.

b. Plans for international travel.

Meeting 1300 hours 23 March 1978, Rm. 106 Waters, KSU, Manhattan, KS.

Attendees: Richard L. Vanderlip, Edward T. Kanemasu, Tom L. Harvey, W. D. Stegmeier, Elizabeth Varriano-Marston, and Herman A. Praeger, Jr.

1. Financial situation of the project was discussed. We were late placing personnel on the payroll, as a result we did not utilize the budgeted amount during the first four months, Oct. 77-Jan. 78. As of now, the permanent employee payroll is essentially $10,000.00 each month. This includes base pay, fringe benefits and indirect costs. This is the level to be maintained leaving adequate funding for the summer help program. AID has approved all our requests for purchase of non-expendable equipment These requests have exceeded the budgeted amount by $6,000. There are adequate funds for all the programmed activities and projects, although it will require shifting funds within the budget.

2. International travel plans were discussed. Drs. Hoseney and Varriano-Marston, Grain Science, plan to visit ICRISAT and selected countries of North Africa during June. They are to provide the itinerary and purpose of the visit to Al Praeger so he can forward to AID for approval. This will be our first trip request. Early submission of the information to Al Praeger would be appreciated so we can obtain the required approval and know what is required for the trips of Dr. Kanemasu, September and Vanderlip, Stegmeier, and Praeger Aug.-Sept.

3. Summer planting plans were discussed. Seed of the required lines of pearl millet are limited. Arrangements were made by all researchers to obtain the required amount of seed of the desired lines. Seed sources were from Bill Stegmeier, Ft. Hays Experiment Station and the seed collection of Dr. Casady, USDA-ARS, Manhattan, KS. The amount of grain required for Grain Science for its testing programs was discussed. They require five pound samples of genetic lines for their work. Plantings were planned to provide grain in their required amounts.

4. The next planning meeting was discussed and will be 9 May in the Grain Science Conference Room, KSU. Drs. Hoseney and Varriano-Marston will present their preliminary results on the chemical analysis of the lines of pearl millet they have analyzed. A later meeting will be at Ft. Hays Experiment Station to observe the field work and pearl millet production by Bill Stegmeier.

5. The initial input for the semi-annual report was reviewed, discussed and edited. Additional input and revisions are to be provided Al Praeger so the report, except for the financial section, can be completed next week.

The third IN-PROGRESS-REVIEW of the project, "Improvement of Pearl Millet" was held 9 May at 1315 hours in Room 106 Waters Hall, KSU, Manhattan, Kansas.

Attendees: Richard L. Vanderlip, Edward T. Kanemasu, W. D. Stegmeier, R. Carl Hoseney, Elizabeth Varriano-Marston, Herman A. Praeger, Jr. and Aarion Johnson

Mr. Moussa Goube, Agronomy Graduate Student from Niger, presented an informative seminar entitled "Cereal Production in Niger". This was followed by a question period in which Mr. Goube discussed the cropping systems and cultural practices of pearl millet production in the various areas of his country. Crop utilization and harvesting procedures were presented. The cereal chemists were interested in milling techniques and the types of human food that are prepared from pearl millet. This was an interesting and rewarding program providing the principal researchers current information and a better understanding of pearl millet and the socio-economic conditions of the people who grow and utilize this cereal.

Dr. Elizabeth Varriano-Marston, in association with Allan Brettell, Foreign Student Advisor of the International Student Center, Kansas State University, has initiated a program to identify female students and wives of foreign students who utilize pearl millet in their ethnic diet. These personnel will then demonstrate to Dr. Marston the preparation of the various types of foods produced from this cereal. This project should prove more beneficial to the milling and food preparation, nutritional research for Developing Countries than comparing pearl millet to the cereals and food habits of the USA.

Carl Hoseney and Elizabeth Varriano-Marston presented some preliminary results of their grain analysis of pearl millet. These preliminary results

indicate pearl millet is within the range associated with other cereals in the areas analyzed. The one exception is lipids. The free lipids are higher in pearl millet than other cereals. This may be associated with the rancidity problem of pearl millet flour. Further study is required to analyze this association.

There was discussion on the desirability of having a common seed source grown at various locations, especially different latitudes and different moisture regimes. The alpha amylase content of cereals does vary with latitude. Also, there is a variance of the microflora populations associated with cereal grains grown in different latitudes. These differences, if they are found to exist, would be helpful in the digestibility study and the grain storage project to be started soon. This can not be accomplised this year, but should be planned for the 1979 growing season. The project now in being with Puerto Rico for seed increase during the winter season should be consider

There are two visitors to Kansas State University from ICRISAT. Dr. J. S Kanwar, Associate Director of ICRISAT will be here 14-15 June. His schedule while here has not been completed. Dr. Francis Bidinger, Cereal Physiologist, ICRISAT, will be here 16-17 May. His schedule is completed and will be provided in the next day or so. Each of the researchers is scheduled to meet with Dr. Bidinger, plus attend the luncheon in the Union.

International travel was discussed. Carl Hoseney and Liz Marston depart 12 June and return 3 July. Requests for the other international travel have been initiated. AID does require a trip report for international travel. This is to be an informal report including dates, places, accomplishments, and personnel contacted.

All costs associated with international travel are legitimate expenses, i.e. cost of passport, visas, travelers checks, immunizations, etc.

The next In-Progress-Review will be 14 July, Room 106, Waters Hall upon return of Drs. Hoseney and Marston from their international travel.

The fourth IN-PROGRESS-REVIEW of the project, "Improvement of Pearl Millet", was held 14 July at 0830 hours in Room 106, Waters Hall, KSU, Manhattan, Kansas.

Attendees: Richard L. Vanderlip, Edward T. Kanemasu, W. D. Stegmeier, Tom Harvey, R. Carl Hoseney, Elizabeth Varriano-Marston, Herman A. Praeger, Jr., the primary researchers, plus John Palmer, graduate student, Agronomy, pearl millet yield trials. Visitors were Dr. Mary Beth Kirkham, Plant Physiologist, Oklahoma State University, and Dr. Kaoru Matsuda, Plant Physiologist, University of Arizona.

Carl Hoseney and Liz Marston returned from their international travel 3 July. Utilizing slides they presented a report of their trip. The trip report will be provided as a separate document.

The financial conditions of the project were discussed. As limited

funds were utilized during the first quarter of the project, it appears that the first year's budget will not be spent by 30 September. The current level of expenditure is very close to the budgeted amounts. There should be no concern of the amount expended on the internal categories of the budget. The funds should be utilized in the best possible manner to fulfill the objectives of the project. The internal categories of the budget can be adjusted to meet the requirements of the separate projects. Next year's budget will be realigned to include this year's carry-over funds at a later committee meeting.

There was discussion on the scheduling period and what grain quality analyses could be accomplished. Bill Stegmeier, plant breeder, desires the results of the grain quality analysis to be utilized along with the agronomic selection factors so he can plan the recombination breeding program to be utilized in the winter nursery project in Puerto Rico. The cereal chemists need to know what quality analyses would be necessary and the dates the results are needed. It was indicated the October-November period was the busiest period in the cereal laboratory. The plant breeder needs the results early for December planting. The number of analyses required should be selected germplasm to reduce the workload from thousands of samples to hundreds. The details of this project will be coordinated by Bill Stegmeier with Carl Hoseney and Liz Marston.

The contract with the Puerto Rico Agricultural Experiment Station for the winter nursery program was discussed. It was decided to coordinate the pearl millet winter nursery with the sorghum winter nursery to see if these projects could be combined and secure these services at a reduced cost. This will have to be approved by the Superintendent of the Fort Hays Branch Experiment Station. This project was assigned to Al Praeger. If the coordinated project is not approved, then a contract with the Corozal Substation, Puerto Rico Agricultural Experiment Station, Mayaguez, Puerto Rico, the same as this year, should be initiated.

The seed and grain exchange program was discussed. On 16 June a letter was dispatched to Permit Unit, USDA-APHIS-PPQ, Hyattsville, MD requesting information on this project. To date there has been no reply. Kansas State APHIS permit for introduction of sorghum was terminated upon retirement of Dr. Edmonds. Texas has an APHIS permit for millet. Nebraska has APHIS permit for sorghum. This was discussed with representatives of Texas A&M and Nebraska. Nebraska is not interested. Texas A&M may be interested for a fee. No financial considerations were discussed, but it appears this project could be expensive. The cereal chemists are concerned about the treatment of the grain sample. They do not want the sample heat treated or chemically treated that would change the composition of the endosperm. They are not concerned with the viability of the germ.

The per diem rates for foreign travel were distributed to the members. Carl Hoseney suggested that these rates be studied. It will be helpful to overcome the initial cultural shock when arriving in the foreign countries especially when you have to pay $100 per day for a hotel room with no plumbing and an air conditioner that doesn't operate.

The Title XII program which is being developed at KSU was discussed. This proposed program is a continuation of the present program with expansion and refinement in selected areas.

The next scheduled IN-PROGRESS-REVIEW will be at Fort Hays Branch Experiment Station 5 October upon completion of the international travel.

The fifth IN-PROGRESS-REVIEW of the project, "Improvement of Pearl Millet", was held 5 October 1978 at 0830 hours in the auditorium conference room, Fort Hays Branch Experiment Station, Hays, Kansas.

Attendees: Richard L. Vanderlip, Wm. D. Stegmeier, Tom Harvey, R. Carl Hoseney, Elizabeth Varriano-Marston, Herman A. Praeger, Jr., the primary researchers; Dr. Robert I. Jackson, AID, Washington, D.C.; Bill Phillips, Superintendent, Ft. Hays Branch Experiment Station; John Palmer, John Gardner, Mithlesh Kumar, Agronomy Graduate Students; Bill Mason, Christopher Lai, Adelaide Beleia, Dansou Kossou, Grain Science graduate students; and Barry Michie, Department of Sociology, KSU, Title XII project.

Richard Vanderlip, Bill Stegmeier, and Al Praeger returned from their international travel 20 September. Richard Vanderlip, using slides presented a report of the trip.

Dr. Kanemasu returned from his international travel 1 October. He was unable to attend this meeting and will present his report at the next meeting.

The group then toured the experimental plots of Bill Stegmeier on the Fort Hays Branch Experiment Station. This has not been a good crop year for summer annual crops. There was no precipitation July, August, and early September with temperatures higher than normal. Many entries did not produce grain. Bill Stegmeier explained his research with pearl millet, hybrids, populations, yield trials, use of male steriles and seed increases located on the various areas of the station.

Funding for fiscal 1979 was discussed. None of the activities utilized all the funds allocated for fiscal 1978. There was discussion concerning the shifting of funds within the various line items for fiscal 1979, to be aligned with the actual needs of the researchers. Dr. Jackson indicated that reasonable requests to AID for shifting of funds within the various line items should be no problem.

Grain Science requested information on how to budget pass-through funds. They feel a need to support a scientist or technician in a LDC and provide resources for supplies and equipment as it is difficult to obtain grain samples from LDC's for analysis that have not been sterilized by heat treatment changing the chemical composition of the grain. This should be considered for this project and the Title XII proposal. Although this was not resolved, it lead to the discussion of what size and number of samples were required. Grain Science is not concerned with the viability of the germ, but does not want the grain chemical composition altered nor the grain contaminated for human consumption. Bill Stegmeier has a different requirement on the importation of germplasm. Dr. Jackson will provide us the names of personnel to contact APHIS to resolve this problem.

The work schedule for this fall was discussed. Bill Stegmeier desires chemical analysis of grain samples so he can plan the recombination for the winter nursery program in Puerto Rico. Grain Science may not be able to accomplish this in the desired time. If they cannot do all the work, the protein analysis will be done in the agronomy laboratory by hiring extra student help, similar to last year. Fort Hays Branch Experiment Station is to complete the memorandum of understanding with the Puerto Rico Agricultural Experiment Station for the winter nursery project.

Chemical analysis of the hybrids provided by Dr. Burton has not been accomplished. John Palmer is to provide the grain samples to Grain Science for analysis, so this information along with the agronomic information of the hybrid yield trial can be provided Dr. Burton.

The analysis of the grain of the same population grown in various areas of the state to ascertain environmental influence on grain chemical composition is not completed. John Gardner is to provide the grain samples to Grain Science for analysis.

The 1979 seed and grain requirements were discussed. John Gardner has seed for three lines for his study but requires seed of two more lines. Bill Stegmeier will provide the seed.

Al Praeger is to check with Bob Mills, Entomology, on their grain requirement for the grain storage study for Title XII.

There may not be sufficient seed for John Palmer's hybrid yield study for next year. If not, Bill Stegmeier will grow the seed in the glasshouse this winter. This study has been expanded to include plantings at Manhattan, Hays, St. John, Minneola, and Garden City.

Bill Stegmeier is to develop the entries and provide the seed for the 1979 yield trials.

Agronomy is not presenting any papers on the results of the research of this project this fall. There is not adequate time to complete the work and analyze the results for this year's meetings. Papers are being prepared for next summer's American Society of Agronomy meeting at Fort Collins, Colorado. Grain Science did not present papers at this fall's meeting, but will make presentations next fall.

The results of this year's research and the input to the annual report is to be provided to Al Praeger by 10 December so he can prepare a draft of the annual report to be completed at our next IN-PROGRESS-REVIEW.

III. International Travel

Trip Report for Drs. R. Carl Hoseney and E. Varriano-Marston
12 June - 3 July, 1978

On the first leg of our trip we stopped in London, England and Detmold, Germany to visit scientists working on cereals. We arrived in London on June 13th and immediately traveled to Sharnbrook, Beds., where we visited Dr. Doug Barnes at Unilever Corporation. After a tour of the facilities, we had a round table discussion with scientists on such topics as the role of starch in baked product quality, and new instrumentation techniques for evaluating differences in grain quality.

On June 14th and 15th, we traveled to Detmold, Germany, where we visited the Federal Research Center for Cereal and Potato Processing. Dr. W. Seibel, Director, arranged meetings with scientists to discuss their work on (1) milling and baking, (2) starch chemistry, and (3) analytical techniques for evaluating grain quality. One scientist, Dr. W. Nierle, demonstrated a gel electrophoretic technique that he is using to characterize cultivars of wheat using a single wheat kernel. This technique may be applicable to the study of millet cultivars.

We arrived in Bombay, India on June 15th. The following day we visited the Bhabha Atomic Research Center as the guests of Dr. S. Rao. Scientists at the center described the various ways they were using atomic energy to preserve foods. For example, they are investigating the use of low doses of irradiation to inhibit sprouting in onions and potatoes, to increase the shelf-life of mangos, bananas, and seafood, and to disinfect grains such as wheat and rice. In addition, they are using irradiation in mutation breeding experiments particularly with groundnuts and flowers.

On June 17th we flew to Hyderabad where we were met by Dr. Jambunathan, ICRISAT Biochemist. Monday (June 19th) we started on the program (see attached itinerary) that was arranged for us by Dr. Jambunathan. Mr. Marayana gave us an overview of the ICRISAT program and objectives and then we visited with Mr. K. E. Rao and Dr. S. Appa Rao on sorghum and millet germplasm collections. They indicated that they had collected 17,000 lines of sorghum and 7,000 lines of millet. A number of cultivars of these grains were shown to us to emphasize the wide variations in seed size, head type, etc.

Later we talked to Dr. van der Maesen about the pulse germplasm collection and the problems involved in maintaining pearl millet lines.

Our next discussions were with Drs. L. House and D. S. Murthy on the sorghum program at ICRISAT. We exchanged ideas about ways to measure grain quality and tests that might be used for rapid screening of sorghum lines. They demonstrated the chapatti preparation technique that they were using in their studies. Their comments have prompted us to study the loss of quality in chapatties during storage.

An overview of the entomological work being conduted on cereals at ICRISAT was presented by Dr. J. C. Davies. He talked to us about the work that they were conducting on shoot flies and also studies on pheromones.

We discussed the pearl millet improvement program with Mr. D. J. Andrews. He was one of the first who mentioned the current research emphasis on grain yield rather than increasing protein content or quality. He pointed out that many nutritional experts in India were encouraging breeders to concentrate on yield because they feel that the majority of the people are consuming sufficient protein but had diets low in calories. We tend to agree with that conclusion. Mr. Andrews also described work they were doing on the relationship between protein content and starch content.

The following day (June 20th) we visited with Dr. M. von Oppen of the economics program. He is analyzing market samples of sorghum and millet on the assumption that those qualities which are consistently associated with high market prices are preferred and vice versa. This approach will allow him to measure the intensity of preferences for certain characteristics. We felt that his data may be extremely helpful in identifying good and poor quality grain samples for study.

Later that morning we talked to Dr. Jambunathan (Biochemistry) about his program on quality evaluation of millet and sorghum. He gave us a clear idea about the kinds of research they are doing, including physical and chemical tests for grain quality. We made arrangements to have "good" and "bad" quality grain samples shipped to us for chemical and physical characterization.

In the afternoon we visited the Andhra Pradesh Agricultural University in Rajendranagar. We talked to millet plant breeders Dr. K. N. Murthy and Dr. N. G. P. Rao. Again, they emphasized the importance of grain yield and stability of yield to increase the amount of food available to consumers. They described the various geographical areas in India where millet is grown and some of the problems they have had with the disease susceptibility of some high yielding varieties.

On Wednesday (June 21) we visited the National Institute of Nutrition where we talked with Drs. Srikanthaiah, Belvady, Pant and Bhat. They described some interesting work that was done which related the ratio of leucine/isoleucine in sorghum to the metabolism of nicotinic acid. They suggested that this ratio was as important as the lysine content of the grain. In addition, they described the interrelationships that often exist between parasites, mycotoxins, and food intake in Indian diets.

We spent that afternoon with Dr. Geervani at the Home Science College. She demonstrated the procedures used by the villagers to grind millet and the types of utensils employed in home preparation of foods from millet and sorghum. Our discussions with her will be extremely helpful in organizing laboratory procedures for the evalua-

tion of millet quality.

On June 22nd, we visited the grain markets in Hyderabad, and a pulse mill. Early in the evening we flew out of Hyderabad to Bombay on our way to Khartoum, Sudan.

We arrived in Khartoum, Sudan, on Friday (June 23rd) evening and contacted Drs. Sitt Badi and A. Mustafa the following day. On Sunday and Monday we visited the Food Processing Research Center. Scientists are experimenting with adding up to 20% sorghum or millet to yeast leavened bread. In addition, they have developed a number of snacks made from sorghum. Experiments are also being conducted on the pearling of sorghum and millet. Drs. Badi and Mustafa also demonstrated how to make kisra (unleavened, fermented bread) from millet.

On June 27th we left Sudan for Kano, Nigeria. Unfortunately, we were unable to reach our contact in Zaria so this part of the trip was not productive. We traveled to Lagos on June 28th and had to spend two days there before getting a flight out to Dakar on June 30th. The remainder of the trip we spent trying to get back to the U. S. We did learn the importance of having reliable contacts in developing countries, as well as not to rely on the cable or telephone service as a communicative tool.

Trip Report of Richard L. Vanderlip, William D. Stegmeier, and Herman A. Praeger, Jr., 18 August - 20 September, 1978, Contract AID/ta-C-1458, Project 931-1040, "Improvement of Pearl Millet"

The party departed home station 18 Aug. traveling to Chicago, London, England and Kano, Nigeria, arriving 0500 hours 20 Aug. We were met at the Kano air terminal by Dr. Shadrach Okiror, who was most helpful in assisting us through the incountry processing and customs procedures. Dr. Okiror is the ICRISAT (International Crop Research Institute for the Semi-Arid Tropics) millet breeder stationed at Zaria, Nigeria and has a cooperative millet breeding program with the IAR (Institute for Agricultural Research), Nigeria and Ahmadu Bello University, Zaria, Nigeria. That morning Dr. B. B. Singh, ICRISAT millet breeder for the ICRISAT West Africa Cooperative Program located at Maradi, Niger and Mr. Botorou Ouendeba, CNRA (Centre National de Recherches Agronomiques) the Niger national program, Maradi, Niger, joined us to be with us during our visit in Nigeria and were our hosts for the Niger visit.

The morning of 20 August we traveled by automobile to Zaria, Nigeria observing the agricultural practices of the area and the harvesting of the ripened pearl millet crop. Many stops were made to observe and take pictures of the crops, inter-cropping systems, equipment utilized and the manual labor required in their farming operations. During the afternoon we toured the area northwest of Zaria toward Kaduna where pearl millet is grown in a different ecological area than we observed earlier. In this area there are larger farms, some are mechanized resulting in mono-cropping systems.

This is good crop production year for this portion of Nigeria, not only for pearl millet but for sorghum, maize, ground nut, cowpea, yams, and vegetables.

That evening Dr. Ango Abdullahi, Director, Institute for Agricultural Research, Nigeria invited us to his home for dinner. In addition to our party, in attendance were the Deputy Director and Department Heads of the Institute for Agricultural Research who have the additional responsibility as Department Heads, Ahmadu Bello University, Zaria. This was an enjoyable way to commence our international coordination in the relaxed environment of a lovely home.

The organization of our Nigerian visit was coordinated by Dr. Abdullahi, Dr. Joe Yayock, IAR Agronomy Section, both Kansas State University graduates and former students of Dr. Vanderlip and Dr. Okiror, graduate University of Wisconsin.

The working hours in the semi-arid tropics are different than ours. They start work 0600 hours, work until noon. They return later in the afternoon to complete the day. Our first meeting 21 August was 0700 with Professor J. H. Davies, Deputy Director, IAR, who briefed us on the responsibilities, organization and resources of IAR. Then we had thirty minute briefing and discussion periods with Professor Caswell, Entomology; Professor Arokoya, Director of Extension; Dr. Egharevba and Yayock, Agronomy; Dr. Leleji, Plant Breeding, Dr. Abalu, Agriculture Economics; and Dr. Ogborn, Weed Research. These were forthright and informative sessions. They have talented and trained personnel to organize and administer their programs.

Their goals are similar to ours, but their problems social-cultural practices and resources are different. This makes it difficult to coordinate our research efforts to assist in solving their problems.

Rain cancelled the afternoon visit to the experimental plots and breeding nursery.

The morning 22 August we drove to Kano. Financial arrangements were completed at the bank for our departure from Nigeria. This is not a simple procedure in this country.

In Kano our first meeting was with Alhaji Jibril Wudil, Chief Agricultural Officer, Ministry of Agriculture, Kano State, Nigeria. This position is appointed by the governor and is considered the most influential position within the state government other than governor for this agricultural state. The effective administration of this office is essential for political longevity.

Mr. Wudil was pleased to learn of our research effort and expressed his appreciation that we were coordinating our work with their research. As pearl millet is the dominant crop of Kano state he is interested in any effort that will enhance the stability of the crop and increase quality and yield. He instructed Dr. Yayock,

our escort, to insure effective coordination of IAR and KSU research that would be mutually beneficial.

Mr. Wudil then explained the programs they had to improve the millet crop. The increase in use of chemical fertilizer, especially in areas of higher rainfall is a program supported by the state. Now a majority of the farmers in the southern 2/3 of the state are utilizing chemical fertilizer. He foresees the farmers coming to sole cropping systems. The cost of labor is getting too high. They have programs for utilization of oxen and small tractors. This is the trend of the future.

This was an informative meeting with an influential member of the state government.

The afternoon schedule started with a briefing by Dr. Ramesh B. Thakare, Millet Breeder, Kano Station IAR. This was followed by a discussion with Dr. Fowler and Dr. Selvaraj and Mr. Kaigama of the millet improvement program Kano Station. Then we toured the millet breeding nursery. This nursery is a duplicate of the work at Zaria that we were unable to visit.

This is a large nursery with thousands of entries, well organized and maintained. The entries include local varieties, germplasm from other acreas of the country, seed from other countries of Africa, the ICRISAT material and selections from the World Collection. They are evaluating all this material not only on agronomic characteristics but in disease and weed nurseries (downy mildew, ergot and striga). There is great diversity in this material. From this they are selecting, recombining and breeding for improved populations, varieties, synthetics and hybrids for the future. This is an impressive research project.

The remainder of the day was traveling north through the arid region of Nigeria to Maradi, Niger. The cropping system changes rapidly as one goes north into that sandy desolate region. The trip was not monotonous. We had to go through customs and departure procedures for Nigeria and the entry process into Niger. This was a religious day for the Moslems and we arrived at 1900 hours which is the time they break the fast. Nothing transpires until they have eaten. Finally departing Nigeria we arrived down the road at the Niger entry in time for prayers which is attended by all the men. After observing Moslem evening prayer, we were cleared to depart for Maradi.

Dr. B. B. Singh, ICRISAT Millet Breeder, ICRISAT West Africa Cooperative Program, Maradi, and Mr. Botorou Ouendeba, Millet Breeder, Centre National de Recherches Agronomiques (CNRA), Maradi, who were with us during the Nigerian visit, were our hosts.

The morning of 23 August we had a conference with Dr. Ousseini Sidibe Director of Agricultural Research, Centre National de Recherches Agronomiques (CNRA), Maradi. Dr. Sidibe was familiar with our research project as he just returned from Columbia, Missouri where he was a consultant on the proposed Title XII program.

We then visited the research plots of Mr. Ouendeba of the Niger National Program. This is a well organized and maintained project. He has developed many materials having dense heads of greater diameter increasing the number of seeds per head. These heads are short compared with some of the Senegal types. The farmers who visited the plots are very impressed by this development. He has done considerable work combining selected characteristics into the local populations and varieties and released the improved seed to farmers. Disease nurseries are include in his project.

We were then scheduled for a visit with the Prefect of Maradi (governor of the state). Diallo Ahi Bodaro greeted us in his office. This was an unusual protocol visit. The Prefect asked questions and invited discussion. His first question was "How can I be sure research is going to help the farmer?" Other subjects included: Is the research on human food quality oriented toward the Lesser Developed Countries, the possibility of ratooning pearl millet in Niger and then he lead a discussion on the organization of field days to show farmers the results of research. Although it was a brief visit, we appreciated the Prefect including us in his busy schedule.

The afternoon was spent in the ICRISAT plots of Dr. B. B. Singh. This again is a large research effort, well organized and maintained with thousands of entries. It is similar to the plots we saw in Kano.

Later in the afternoon we met with Dr. Clark Harvey, AID sorghum breeder, who is Team Leader, Niger Cereals Project, Maradi.

We were scheduled for another day in Maradi. However, Niger Airlines changed their schedule. The one plane they have flies west Tuesday and Thursday. We arranged to visit the AID office, Niamey, Thursday afternoon and Friday morning and then continued on our scheduled trip.

We arrived Niamey afternoon of 24 August and conferred with Harry Dickherber of the AID office and W. E. Hall, AID, Seed Multiplication Program, Niger.

The next morning continued our discussion with Mr. Hall.

Arrived in Ouagadougou in the afternoon, met by Dr. Peter Lawrence, ICRISAT Millet Breeder. Toured Kamboinse Station; then after a rain visited the millet breeding plots. This is an extensive program which includes the ICRISAT material, World Collection, material from other countries and as Upper Volta does not have a national research program at this time, there is a program for improvement of the local populations and varieties of pearl millet.

25-26 August Vanderlip and Stegmeir accompanied by Dr. Peter Lawrence utilizing a four-wheel drive Land Rover toured Northern Upper Volta in the southern Sahara region of Gorom-Gorom. Praeger encountered a tourist West Africa syndrome and did not accompany them on the trip.

Monday 28 August, Stegmeier accompanied Dr. Lawrence and Dave Andrews, ICRISAT Millet Breeder, Hyderabad, India who was visiting the project, evaluated the entries in the breeding nursery. Praeger and Vanderlip met with Drs. Stoop and Van Staveren, ICRISAT agronomists, discussed their research projects and toured the field experiments. There are many cultural practices that could be implemented by farmers to increase crop production compared with current farming practices.

29 August was spent with Dr. C. M. Pattanayak, ICRISAT Team Leader and Sorghum Breeder, Upper Volta. His research program was discussed and then we visited the research plots. We then visited a village and farmers fields where he has initiated a program to ascertain if the local farmers will accept the use of hybrid grain sorghum where they have to purchase the seed each planting season. In this village Dr. Pattanayak selected one farmer and provided the hybrid sorghum seed. The farmer was to plant it in two or more fields along with his normal sorghum. The farmer is to compare the hybrid with his own sorghum. He is also to explain what he is doing with his neighbors. The hybrid provided by Dr. Pattanayak is shorter in height than the local variety and has a deeper green color making it easily identifiable. Although the crop was not mature it did appear that the hybrid would outyield the local variety. Dr. Pattanayak was sure that the hybrid would significantly outyield the local material. To entice the farmer to cooperate in this program, Dr. Pattanayak provided the hybrid seed for this crop year. He will provide hybrid seed next year if the farmer convinces three other farmers in his locality to purchase and plant hybrid seed. The local interest in this project is high. Whether it is a successful project will not be known until next planting season. The cost to initiate this local project was one kilogram of hybrid seed.

30 August we completed our coordination at Kamboinse Station and departed for Dakar, Senegal.

31 August had a conference with Dr. Claude Charreau, ICRISAT West Africa Coordinator. We then visited the AID office and conferred with Mr. A. Hartman. Mr. Schoonover and Mr. Livingston were out of town.

That afternoon Dr. Charreau scheduled a meeting with Dr. Louis A. Sauger, Director General, Institut Senegalais De Recherches Agricoles. This was an interesting and informative meeting. Dr. Sauger was interested in the KSU project, which was explained. He then explained the national program and the West Africa and ICRISAT programs and where they are cooperating. In addition to the research at Bambey Station where we will visit tomorrow, he indicated the greatest research needs are in grain quality. This was further defined as higher digestible protein, fatty acid content that does not cause rancidity and high energy content. To solve some of their problems they have organized an Institute of Food Technology, to assist in the research. Prior to this the quality tests were usually visual and more scientific work is necessary.

1 September, with Dr. Charreau drove to Bambey Experiment Station, Bambey, Senegal. This is the site of the original Franco West Africa Experiment Station. It is no longer a Western Africa Station; since

independence it is organized on a national basis. Here we met with Dr. G. Beye, Director, Bambey Station. He gave an excellent briefing on the organization of the research program and the source of support. They utilize a multidiscipline team approach to conduct research projects. They are organized into seven groups: soil and water management, fertility management, cereal improvement (millet, sorghum, maize legume improvement (ground nut, cowpea, soybean), plant protection, techniques and systems (livestock, engineering, post harvest), and applied research and economics. The source of the financial support is 65% Senegal, 30% France and 5% USA, ICRISAT and private sources.

We were briefed and had discussions with Dr. Aboubakry Sarr, Chief millet breeder, and Dr. Claude Dancette, Agroclimatologiste, and then toured the millet plots with Dr. A. Lambert, ICRISAT millet breede and Dr. Claudie Lambert, CNRA millet breeder.

The agricultural practices in Senegal are different than the other countries of western Africa. They utilize animal power and have some mechanization, with corresponding tillage implements. Most of the fields are mono-cropped, but there is some intercropping of millet and cowpea. There is a fertility problem and on the sandy soils and this is serious. The research effort at Bambey addresses these areas.

Bambey Station is well organized, effectively administered, with a large staff and has a comprehensive program for all areas of agricultural production. Our previous visits were to research sites where millet breeding and production was the major effort. This was the only comprehensive agricultural research station we visited in Africa.

2-3-4 September travel Dakar-Roma-Instanbul-Tehran.

5 September arrived Delhi, India 0230 hours. Pam Am misplaced our luggage and after customs and claim procedures arrived at the hotel 0600 hours. At 1000 hours meeting with Fletcher E. Riggs, AID Office, Delhi. They prepared a schedule of our time while in Delhi. With the flood we could not travel to Hissar and Ludhiana as planned so had to rearrange the schedule.

That afternoon we met with Dr. S. C. Pokhriyal, Senior Millet Breeder, Genetics Division, Indian Agricultural Research Institute (IARI) and Dr. D. P. Thakur, plant pathologist, IARI. They gave an excellent briefing on the millet improvement program which was initiated during 1962 and its current status. The hybrid millet program started with forty hectares in 1965 and increased to 2.2 million hectares in 1970. During 1971 downy mildew destroyed the hybrid millet crop. This was due to lack of diversity in the first hybrids which Tifton 23, male sterile developed by Dr. Burton, Tifton, GA, was one of the parents and is highly susceptible to downy mildew. Hybrids have now been developed that are tolerant to downy mildew and it no longer is a problem. The current problem is ergot, followed by rust and smut. It appears that ergot may be as devastating as downy mildew was unless sources of resistance are identified.

Although they are not concerned with the protein content of millet grain as it has high protein content compared to other cereals, they have inbreds that produce 27% protein.

Plant breeding and genetics will not solve all the problems of millet production. As millet is grown on the poorer, lighter soils, fertility and salinity are problems. Improvement in utilization of fertilizers, crop rotation utilizing ground nut and improved tillage operations are areas of emphasis for increased millet production.

This was an interesting and informative afternoon spent with these talented researchers.

6 September, flew to Bombay and hired taxi to Poona. Arrived in evening.

7 September, meeting with Dr. G. Harinarayana, Project Coordinator millet, College of Agriculture Shivaji Nagar, Poona. In addition to his work at the college, he is coordinator for the All India Millet Program which includes twenty centers throughout India located at colleges or institutes. He was familiar with our research program as he was at Columbia, Missouri for the Title XII review. He gave a briefing of the scope of work in the All India Program. We were fortunate that Dr. V. P. Gupta, Head, Department of Genetics, Punjab Agricultural University, Ludhiana, was visiting that day. He was one of the stations cooperating with Dr. Harinarayana in the All India Program. He discussed his program. We then visited the pathology disease nursery. They have identified many entries having resistance to the various pathogens.

After an enjoyable Indian vegetarian lunch, we returned to Bombay and Delhi.

8 September arrived Agra, met at the airport by Dr. S. P. Singh, Head Department of Botany, Raja Balwant Singh College. We were then invited to the home of Dr. Roshan Singh, President of RBS College, for a working breakfast. This was a rewarding and enjoyable exchange of ideas with the president of the College and Dr. S. P. Singh our escort.

We had scheduled visits with Dr. S. N. Temari, Pathologist, RBS College; Dr. B. P. S. Chanhan, Department of Botany, RBS College; Dr. G. S. Lavania, Department of Botany, RBS College and Dr. R. P. Narwal, Department of Botany, Kurukshetra University, Haryana who was visiting Agra. These were informative discussions concerning their millet research projects.

We were then invited to the home of Dr. S. P. Singh for a late lunch and had time for a brief tour of historic Agra prior to going to airport for trip to Jaipur. This was a productive day made more enjoyable by our gracious hosts.

We arrived in Jaipur in the evening and were met by Dr. K. L. Vyas, millet breeder, University of Udaipur Durgapura. We were billeted in the opulent accommodations of Rambagh Palace.

The morning 9 September we were met by Miss Uma Menon, Economic Botanist, our escort, and Dr. R. L. Mathur, Joint Director (Research) Agricultural Research Station, University of Udaipur Durgapura, Jaipur. We went directly to the research plots where we were met by the researchers with their assistants and toured all the millet research projects. This is one of the stations of the All India Program. They have an extensive research program in all aspects of pearl millet production. This is a well organized and managed program. It is similar in scope to the other stations of the All India Program but was much larger in size and number of entries.

We returned to Delhi.

Arrived at Hyderabad 2110 hours 10 September. Met at the airport by Dr. J. S. Kanwar, Associate Director (Research), Dave Andrews, millet breeder and Fran Bidinger, cereal physiologist ICRISAT. Were given copy of itinerary during our visit.

The morning 11 September was spent with Dave Andrews, millet breeder, discussing his project and visiting his plots. That afternoon Bill Stegmeier was with Drs. S. C. Gupta, K. Anand Kumar, and K. N. Rai, plant breeders, for detailed observation of the breeding materials in the ICRISAT program. Vanderlip and Praeger were with Dr. B. A. Krantz, farming systems program leader, who was presenting a seminar on land use development to a group of visitors from Australia and Sweden. This included a tour of the ICRISAT area to show examples of the implementation of the programs. Following this session, they met with Dr. M. B. Russel, consultant, and Dr. S. M. Virmani, project leader, Computer Modeling ICRISAT.

The next day Stegmeier was with Dr. R. J. Williams, cereal pathologist, and Drs. S. D. Singh and R. P. Thakur, plant pathologists, ICRISAT, discussing their projects in identifying disease resistance and visited their research plots. Vanderlip and Praeger were with Dr. F. R. Bidinger, cereal physiologist, and Drs. R. K. Maiti and G. Alagarswamy, plant physiologists, ICRISAT. The research programs were discussed. Arrangements were made for exchange of experimental data. New publications and drafts of proposed publications were obtained. The afternoon was spent in the field observing the research plots.

Dr. Vanderlip contacted Paul Gibson, Ph.D. candidate, Texas A&M, who is completing his research at ICRISAT. After this visit, Dr. Vanderlip contacted Dr. Dallas Oswalt, Training Officer ICRISAT, and arranged a similar program for one of his students at KSU to complete course work at KSU and perform the research at ICRISAT.

The next day Dr. Vanderlip had conference with Dr. Virmani and associates on computer modeling. Then a short conference with Dr. L. R. House, sorghum breeder, ICRISAT, who was at Columbia, Missouri for the Title XII review.

This completed our schedule at ICRISAT. It was a very productive visit. One must be impressed or almost overwhelmed at the magnitude and scope of the Institute, the highly qualified personnel, management

of the operations, results obtained and the friendly cooperative attitude of all personnel.

Dr. J. S. Kanwar, Associate Director (Research), ICRISAT, was departing on the same plane allowing time to visit during the flight.

After a stop in Hong Kong arrived in Honolulu and returned home 20 Sept.

Trip report of E. T. Kanemasu, September 2-30, 1978, England (Nottingham University), India, Malaysia, and Philippines

ENGLAND

The Nottingham University group headed by Dr. John Monteith and funded by Ministry of Overseas Development is studying the limitation imposed by climate and soil on the yield of monocultured and intercropped farming systems in the tropics. The primary crop being studied is pearl millet. They are cooperating with ICRISAT on a research project at Hyderabad. They are collecting data both at Sutton Bonington (Nottingham) and Hyderabad. Their work is directly related to the work being done here (KSU) on the growth and development of millet, distribution of dry matter, and water relations of millet. We have made plans to exchange information on a regular basis. The research group consists of Peter Gregory, Geoff Squire, Chin Ong, and Bruce Marshall.

Two interesting experiments being conducted are 1) the effect of photoperiod on growth of millet and 2) tillering response of millet. They have found that millet is very sensitive to photoperiod.

INDIA

I visited Water Technology Center, Indian Agricultural Research Institute in New Delhi where I met with Drs. A. M. Michaels and S. K. Sinha. They are primarily interested in the engineering aspects of irrigation, and plant water relations. Dr. Sinha is a plant physiologist involved in wheat physiology.

In Hyderabad, I visited with Drs. S. M. Virmani, M. V. K. Sivakumar and Huda in the Agroclimatology section of Farming System Group. Dr. Virmani has studied the rainfall distribution (spatial and temporal). The pronounced wet and dry seasons in Hyderabad are quite interesting. These rainfall probabilities are used in the cropping system for selecting crops to suit the weather.

The millet physiology program was visited (Drs. Alagarswamy and Bidinger). Millet types are broken into the West African and Indian types. The West African types have fewer panicles (tillers) but are larger than the Indian types. One potential to improving yields in the West African types may be in breaking the dominance of the main shoot.

The Soil Physics section of ICRISAT is headed by Dr. M. B. Russell.

Many of the research programs are joint projects with Agroclimatology such as water, energy, and light studies on Kharif and Rabi crops. The physical characteristics of the red and black soils are being studied. Dr. Russell is working closely with the University of Nottingham group on a cooperative study of millet and groundnut. He has also developed an evapotranspiration and soil moisture model that is agreeing well with measured values.

The most fruitful outcome of my visit was the establishment of a cooperative research project with Drs. Bidinger and Andrews. The research will be conducted at Hissar (north of Delhi). Several genotypes of millet will be studied. We will make leaf and air temperature measurements. They will make several physiological observations. This will permit our drought screening technique to be tested over a much greater range in genotypes than could have been possible in Kansas.

I presented a seminar on the evapotranspiration and yield model developed by the Evapotranspiration Laboratory. Dr. Bob Wiley of the Intercropping section is interested in the model and its use in predicting various intercropping sequences. He will be sending data sets to us for analyses.

MALAYSIA

I visited the University of Agriculture in Serdang and presented a seminar to the Agronomy Department (Dr. Halim Hassani is Acting Head of Agronomy). The field research sites were visited in which the Belgium work on soil water conservation and tin mining reclamation was discussed. Later in the afternoon, I visited with Dr. Hasim, Associate Director of Fundamental Programs in MARDI.

PHILIPPINES

At Los Banos, I visited with people involved in drought resistance selection, plant water relations and growth modeling. Listed below are the people visited and their disciplines:

Ms. E. Loresto	- Plant Breeding
Dr. S. C. Modgal	- Agronomy Department
Dr. T. C. Hsiao	- Agronomy Department
Dr. V. S. Tomar	- Agronomy Department
Dr. E. P. Pacardo	- Botany Department
Drs. Bhuiyan and Early	- Irrigation and Water Movement
Dr. Zandstra	- Multiple Cropping
Drs. Angus and Morris	- Multiple Cropping
Mr. H. Inoue	- Plant Physiology
Dr. J. A. McMennamy	- Agricultural Engineering

One interesting observation on rice indicated that leaf temperature of drought resistance lines were higher than those of drought susceptible lines. This is what we hypothesized for millet. Presently, they relate drought resistance with thick roots and delayed leaf rolling.

Trip report of E. Varriano-Marston and Carl Hoseney, September 16-22, 1978, Winnipeg, Canada.

We attended the Sixth International Cereal and Bread Congress, September 16-22, 1978, in Winnipeg, Canada. The congress brought together over 1500 cereal scientists from 50 countries and over 200 papers were presented related to cereal production, processing and utilization as well as cereal chemistry and nutrition.

Some of the papers that were presented included a discussion of the preparation of products from sorghum. In addition, a paper was presented by Dr. Reichert (Canada) on the bleaching of pearl millet pigments. Dr. Reichert is working on a pearl millet project at the University of Saskatchewan. He extended an invitation for us to visit his facilities and to discuss the research they are doing on pearl millet.

Some other papers that we attended dealt with methods for analyzing cereals: infrared spectroscopy, electrophoresis, and centrifugation techniques. Dr. Hoseney presented a paper on the functionality of chlorine-treated flour and chaired a session on rice. The rice session stimulated our interest in applying some of the quality tests used for rice to pearl millet quality evaluation.

Dr. Varriano-Marston presented a paper on bread staling and chaired a meeting of the AACC Scholarship Committee.

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A list of project staff members for the period covered by this report

Richard L. Vanderlip - Principal Investigator, Agronomist, Manhattan, KS, .20 FTE - R

R. C. Hoseney - Cereal Chemist, Grain Science, Manhattan, KS .25 FTE - R

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William B. Ndahi - Graduate Student, Agronomy Weed Control, Manhattan, KS, Nigeria Scholarship

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Adelaide Beleia - Graduate Student, Grain Science, Manhattan, KS Brazil student, .5 FTE - R

Christopher Chung Lai - Graduate Student, Grain Science, Manhattan, KS, Taiwan student, .5 FTE - R

Aarion Johnson - Research Associate, Grain Science, Manhattan, KS 1 Jan - 30 June 1978

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Rebecca Caulkins - Secretary, Grain Science, .5 FTE - R

Marianne Orr - Secretary, Agronomy, .5 FTE - R

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Sandra Dassenko, Graduate Student, Food and Nutrition, Manhattan, KS .5 FTE - R

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FTE = full time equivalent

R = research contract

There are nine undergraduate students assisting in the program employed on a part-time basis.

VI. Results of Research

PEARL MILLET BREEDING
[*Pennisetum americanum* (L.) K. Schum]

W. D. Stegmeier

Introduction

Pearl millet breeding and research was initiated in 1971 at the Hays Experiment Station. Since that time, the work has progressed through the initial screening of all of the material available from the Southern Regional Plant Introduction Station at Experiment, Georgia, and the World Pearl Millet Collection to the present stages of development of early maturing lines, hybrids, populations, and composites. At the present time, it is believed that the germplasm base of this project's material is restricted to some extent because of the necessity to use, in a large proportion of the crosses, two varieties from Uganda and one from Ghana, contributing early maturity and increased seed size, and several forage inbreds from Dr. Glen Burton's USDA Project at Tifton, Georgia contributing dwarfness and the A_1B_1 and A_2B_2 cytoplasmic male-sterility and fertility maintainer systems. These materials have been crossed to several of the plant introduction lines, of which 56 are currently in the program, to provide derivatives that are sufficiently early maturing to be usable and amenable to breeding efforts under the conditions imposed by the climate and latitude of this location. At this point, some of these derivatives should and will be back-crossed to the original plant introduction lines to recover more of their unique characteristics and to introduce more variability into the breeding population. Also, several of these materials have reached development stages where they are useful to workers in other disciplines at Kansas State University and have been shared with workers in other states and in Africa.

With the recent acquisition of additional greenhouse facilities, an APHIS permit, and the cooperation of Dr. Joe Martin, plant pathologist on the station staff, a start has been made in obtaining superior materials from Indian, African, and ICRISAT programs. As these materials pass through quarantine restrictions, they will be incorporated into the Kansas breeding program.

The following report summarizes the current status and progress made in this portion of the Kansas Pearl Millet Improvement Program.

Experimental Procedures

All populations, S_1 progeny and F_1 hybrid performance tests were planted with a four-row commercial planter equipped with cone seed feeders. Sowing rates were three times the desired stand and final stands were obtained by hand thinning to populations of 35880 and 47840 plants per hectare in rows 91 cm wide. Nitrogen fertilizer was applied at rates of 0, 33, and 45 kg N per ha depending on the location, objective of the planting, and previous field history. Weeds were controlled with triazine and 2,4-D herbicides and mechanical cultivation. Harvesting of performance test plots was done with a plot combine equipped with "Hesston Head-Hunters" to pick up lodged culms.

Experimental designs used in the performance testing of S_1 progenies and F_1 hybrids were 7 x 7 and 9 x 9 simple lattice designs with three replications. Single-row plots were planted. The initial statistical analysis of the results was conducted as though the tests were randomized complete block designs.

Population Improvement

Six populations and composites, in various stages of development, were grown as part of this project.

The Cycle 2 recombination generation of Hays Millet Population 550 (HMP550) was grown on the Corozal, Puerto Rico Experiment Station during the period of 1 February to 22 May, 1978. Seeds harvested from this nursery were planted to a 0.6 ha field to produce the Cycle 2 S_0 generation. More than 1500 plants were selected at anthesis and self-pollinated by bagging one to five heads per plant to produce Cycle 2 S_1 progenies. Between 400 and 500 of the self-pollinated plants were selected for harvesting on the basis of plant type and conformation, apparent drought tolerance and lodging resistance, head exsertion, seed set, and seed size.

A total of 163 Cycle 1 S_1 selections of Hays Millet Population 1700 (HMP1700) were tested in performance tests. Controls included two sources of HMP1700, the 1975 and 1976 random-mated, mass-selected populations (seed from the 1976 crop formed the 1977 C_1S_0 population), two F_1 hybrids using HMP1700 C_1S_0 population as the male parent, and a grain sorghum hybrid, DeKalb C42A+. Due to the large amount of variability in yield resulting from varying degrees of drought stress throughout the test areas, the grain samples of each S_1 selection were bulked before being analyzed for protein content.

The F_2 generation of 1978 Series 2 composite was grown in a 0.57 ha field. This composite was initiated in 1976 by interplanting seeds of a bulk of dwarf PI185642 D_1B_1 and D_2B_1 lines within a block of 233 Plant Introduction Station lines. The resulting F_1 seeds were planted under isolation and allowed to random-mate in 1977. Approximately 1500 self-pollinated F_2 segregates of D_1 and D_2 phenotypes were selected for harvest and threshed in bulk.

The 1978 Series 5 composite of F_1 or half-sib progeny of a bulk cross was planted in an isolated 0.6 ha field and allowed to randomly mate. This composite was formed in 1977 by interplanting the bulked seeds of 30 superior F_4 to F_7 lines of PI185642 D_2B_1 throughout an isolated 0.8 ha planting of the world collection composite in a ratio of one D_2B_1 row to 12 WCC rows. Seeds harvested from the primary heads of the dwarf plants were sown in the 1978 planting. Primary heads from several hundred superior, tall F_1 plants were harvested and threshed in bulk.

Senegal population was planted in an isolation block of 0.12 ha in size. This planting was to be used to provide a supply of seed for experimental plantings in 1979.

Hays Millet Population (HMP559) was initiated in 1971 by harvesting open-pollinated seed of 22 superior Plant Introduction Station lines. This population has been advanced by mass-selection and with the climate of this area eliminating much of the late-maturing portion of the population. This population was planted in an isolated 0.8 ha location that had been cropped continuously for two years. Subsoil moisture and soil fertility reserves were depleted. Fertilizers were not applied in an attempt to place the planting under low fertility stress as well as moisture stress as an aid in selection.

F_1 Hybrid Development

Emphasis has been placed on the development of large-seeded female parents to reduce the hazards of germination and seedling establishment of F_1 hybrids. The development, maintenance, and the initial seed increases of cytoplasmic male-sterile and male-fertility maintainer lines are performed in a backcross nursery planted on upland soils. The 1978 nursery contained about 125 pairs of A_1 and B_1 lines, 75 pairs of A_2 and B_2 lines and 125 B_1 and B_2 selections. Depending on the stage of development, two to five B-line plants are selected for use as pollen parents to fertilize several female plants within each pair. Additional selection is practiced at harvest to eliminate undesirable materials. Additional B_1 and B_2 materials were planted in another location for between and within-family selection.

Selection and advancement of new male-fertility restoring lines to be used as male parents of F_1 hybrids is conducted primarily on upland sites. As with the development of the female parents, most of the restorer lines are being derived from plant Introduction Station materials. Fifty-six PI's are presently represented within this group of materials with development ranging from F_1 to F_6. Advanced generation lines showing desirable characteristics at anthesis are self-pollinated and crossed to A-lines planted throughout the nursery to produce experimental hybrids for testing in 1979.

A crossing nursery was planted on a bottomland site where supplemental irrigation water could be applied. A total of 322 R-lines and 42 PI185642 D_2A_1 lines were planted. These R-lines were either parents of F_1 hybrids being grown in performance tests or were selections from superior R-lines. Many of the A_1 lines had been used previously in hybrid combinations or were new lines that appeared promising and were to be crossed to superior R-lines.

Four small hybrid seed production blocks were planted in isolated areas on the station. These blocks each contained 6 to 8 rows of an inbred R-line as a male parent and a single row each of four PI185642 D_2A_1 lines to serve as female parents in an attempt to produce seed of a 4 x 4 diallel. Row lengths varied from 7.3 to 18 m in length, depending on the location and amount of seed available.

A total of 248 F_1 hybrids were entered in performance tests and 19 hybrids with limited seed supplies were placed in an observation nursery. Pearl millet checks used were two HMP1700 hybrids, HMP1700 C_1S_0, and

HMP550 C_2S_0. Three commercial sorghum hybrids, DeKalb hybrids C42A+, E59+, and F-67, were used for maturity, height, and yield comparisons.

Tolerance to the Greenbug Aphid

Cooperative studies by Dr. Tom Harvey and W. D. Stegmeier

Following preliminary studies indicating genetic control for both tolerance and partial tolerance to the greenbug aphid, *Schizaphis graminum*, a second set of F_2 segregating progenies were tested. However, because the parental seeds were obtained from bulk seed lots of the four inbred lines of Georgia hybrid Gahi-1, an excessive amount of variation was encountered. To reduce this variation, the parental lines were grown and self-pollinated in the field. Seeds from these materials have been planted in the greenhouse to be screened for parental reaction to the aphid. Parental lines showing the desired reaction will be used for producing a new set of F_1 and F_2 progenies.

Results and Discussion

Dry, hot weather throughout the summer of 1978 produced drought stress symptoms ranging from moderate to severe in the dryland plantings, even though all of the plantings with the exception of HMP559 and the Senegal Population were located on fields with fair to excellent subsoil moisture reserves. Rainfall received during the June 1 to October 15 period was 17.5 cm compared to the long time average of 32.8 cm. The period of time from late July to October 15, the critical reproductive and ripening period, received only 5.3 cm of rainfall or less than one-third the amount expected. In only three of the 111 years of record keeping at this location, has this portion of the summer and early fall received less rainfall. Several of the rain storms were small and considerable variation was noted in the amounts of precipitation received in different parts of the Experiment Station. Ambient air temperatures were above normal throughout the season with monthly average temperatures ranging from 0.2 to 2.2°C above average.

Selection for apparent drought tolerance was possible within several of the populations, performance tests, and in nurseries of inbred lines. The degree of drought stress exhibited within which selections could be made was varied due to interactions between dates of planting, precipitation patterns and amounts, plant maturity requirements, and soil characteristics of the location of a given planting. Several plantings including HMP559, Senegal population, and two of the isolated F_1 seed production blocks were complete failures due to moisture stress. The male sterilization backcross nursery and portions of several of the performance tests had extensive areas within the plantings that ranged from failure to produce heads and seed to areas of relatively good growth and development. However, some of the isolated plantings, such as 1978 series 5, had good development because they were located in the storm track of some of the small thunderstorms that passed through the experiment station.

Population Improvement

HMP550 C_2S_0 had good plant development due to both a favorable location and its early maturity. However, drought stress occurring after anthesis appeared to be a factor in the development of stalk rot in the base of the culms of many plants. The disease as observed on the millet plants was very similar to charcoal rot, *Macrophomina phaseoli*, seen on sorghum in an adjacent field. Approximately 50 to 75 self-pollinated plants appearing to be disease-free were selected from within areas of the field having a high incidence of the disease. Two hundred of the 400 to 500 S_1's harvested will be selected for Cycle 2 S_1 performance testing. Selection will be based on above average seed size and apparent grain quality.

Variable drought stress ranging from mild to severe occurred throughout the area containing the HMP1700 Cycle 1 S_1 performance tests. As a result, statistical analyses were unable to define significant differences and coefficients of variation ranged from 40 to 54%. Therefore, the selection of the 21 S_1's (see Table 1) to be recombined to form the Cycle 2 population was based on visually apparent qualitative characteristics as well as characteristics subject to measurement. Factors such as synchrony of heading, seed size, density of seed set, plant conformation, and apparent drought tolerance were given a large degree of consideration in the selection process.

Several selections of the same maturity range as seen in DeKalb sorghum hybrid C42A+ lodged severely. This lodging appeared to be due to an interaction between early maturity with good grain yields and charcoal rot induced by drought stress following anthesis. Later maturing selections showing drought reduced plant development and yield had a much lower incidence of charcoal rot.

Seeds of the 21 entries selected for recombining have been sent to the Corozal Experiment Station in Puerto Rico to be grown in a winter recombination nursery.

Growth and development of individual segregates of 1978 Series 2 ranged from poor to good and, as seen in other plantings, the wide range in plant condition appeared to be due primarily to interactions between stages of maturity and drought stress. Early maturing plants usually exhibited good development while plants reaching anthesis at later dates had exhausted soil moisture reserves and were unable to produce seed. The dwarf segregates harvested from this population will be planted in an isolated location, random-mated, and mass-selected for two years. At that time, a portion of the population will again be interplanted within a block of the plant introduction material and intercrossed to gain additional variability. The remainder of the population, if it appears to have a sufficient level of desirable characteristics, will be placed in a recurrent selection program and used as a source of parental material in the production of hybrids and synthetics.

Following three years of random-mating, mass selection for desirable plant and seed characteristics, and the elimination of late maturing types by climatic effects, the bulked World Pearl Millet Collection was used as a male parent in a bulk cross with dwarf derivatives of PI185642 used as the female parents. The resulting tall F_1 bulk, 1978 Series 5, was grown under isolation and random-mated. Dwarf plants to be selected in 1979 will be placed in a program similar to that planned for 1978 Series 2, as mentioned above.

The planned production of HMP559 under low moisture and fertility levels failed because of severe drought. This population will be replanted on the same site in 1979. The object is to eventually recover plant types with increased tolerance to stress conditions. At this time, the population is tall, medium-late in maturity, and long headed with good head and seed characteristics. Eventually, if success is obtained in stress tolerance improvement, dwarfing genes will be introduced into the population.

F_1 Hybrid Development

The rate of advancement of parental materials and the production of F_1 hybrids was retarded because of drought stress. Although several hundred selections were made within lines and progenies of male-fertility restoring materials grown in the upland nurseries, very few crosses were attempted because of poor prospects for obtaining sufficient quantities of seed for testing purposes. Conditions were even poorer in the male-sterilization backcross nursery and only a few pollinations were made. Lines of A, B, and R materials that appeared promising in regard to drought tolerance have been planted in the greenhouse and are expected to produce seed in quantities sufficient for limited testing in the 1979 nurseries. Seeds of over 100 F_1 hybrid combinations were produced in the bottomland crossing block.

Results of the performance trials of 248 F_1 hybrids were similar to those obtained in the S_1 progeny tests. Variable drought stress caused nonsignificant statistical differences and coefficient of variation ranges of 35 to 55%. Ranges in grain yields were 120 to 2330 kg per ha for millet hybrids and 660 to 2340 kg per ha for the three DeKalb sorghum hybrids used as checks. Several millet hybrids in the DeKalb C42A+ maturity class (early) had lower lodging scores than did C42A+ and appeared to be unaffected by charcoal rot. The medium and late maturing sorghum and millet hybrids had low lodging scores but this is probably due to a reduction in mechanical leverage as a result of small heads and seed yields.

Tolerance to the Greenbug Aphid

Preliminary genetic studies in cooperation with Dr. Tom Harvey have indicated that the tolerance of pearl millet to the phytotoxin produced during feeding activities of the greenbug aphid is conditioned by a single gene. These studies also indicated the presence of a factor or factors giving partial tolerance in at least one of the four parental

inbred lines of the Georgia hybrid Gahi-1. However, when additional studies were attempted using F_2 seeds of several additional crosses between parental seeds obtained from several sources of the four inbred lines a considerable amount of variation was encountered both within and between families. Very few of the segregating F_2 progenies were found to fit standard genetic ratios. Since the parental seeds were obtained from bulk seed lots of the four lines, it was assumed that with additional selfing parental seeds with a greater degree of homozygosity could be used to initiate a second cycle of testing.

Combined results of the HMP1700 Cycle 1 S_1 population improvement performance trials, 1977. 1/

	Visual appearance rating score 1-9 1/	Plant height, cm	Lodged plants at harvest score 0-9 3/	Test weight, kg/hl	Grain yield, kg/ha
Average of 21 S_1 selections to be recombined	6.0	80	2.8	78.6	1610
HMP1700 C_1S_0 (1976 random-mated crop)	5.9	83	4.7	78.6	1470
HMP1700 (1975 random-mated crop)	6.5	83	5.6	78.0	1790
1166 x HMP1700 Bulk F_1	7.1	83	4.9	78.6	1580
1212 x HMP1700 Bulk F_1	6.0	81	3	78.6	1770
Sorghum hybrid DeKalb C42A+	6.1	94	6.3	74.7	2960
3-test average of all entries	7.0	75	3.6	78.3	1270

1/ Results are averages obtained from three trials containing a total of 163 S_1 entries.

2/ Visual rating score: 1 = very good to 9 = very poor.

3/ Lodging score: 0 = no lodging to 9 = 90 to 100% lodged.

YIELD AND HETEROSIS STUDIES OF PEARL MILLET [*Pennisetum americanum* (L.) K. Schum]

J. C. Palmer, H. A. Praeger, Jr. and W. G. Stegmeier

INTRODUCTION

Although of high nutritive value, pearl millet [*Pennisetum americanum* (L.) K. Schum] often is characterized by low yields, small seed size, and excessively tall stature (1). In light of these problems, two studies were conducted in order to provide useful data to breeders working to improve this crop. In the first study, selected pearl millet hybrids were evaluated for a number of agronomic characteristics and were compared with commercially available sorghum hybrids. In the second experiment, heterosis was studied among certain parental lines of pearl millet and their F_1 offspring. Significant increases in grain yield have been reported in F_1 hybrids due to heterosis (2).

MATERIALS AND METHODS

Hybrid Studies - Three locations were selected in Kansas for the planting of hybrid yield studies, Ashland Experiment Field, Manhattan; Fort Hays Branch Experiment Station, Hays; and Sandyland Experiment Field, St. John.

At Ashland, F_1 hybrids of pearl millet (obtained from Dr. Glenn W. Burton[1] and Dr. A. J. Casady[2]), were planted on 5 June in two-row plots, 6.1 m long. Row spacing was 75 cm and seeding depth was 2.5 cm. Two commercially available sorghum hybrids (DeKalb C42A+ and C46+) were also planted to compare the performance of millet and sorghum hybrids. 6.1 m of row were harvested. Notes obtained on each of the hybrids were: average plant height, number of heads, weight of grain (adjusted to 12.5% moisture), average head length (of ten heads selected at random), and one thousand seed weight.

Another hybrid study was planted at both Hays and St. John using twelve F_1 millet hybrids (developed at the Fort Hays Branch Experiment Station), two sorghum hybrids (DeKalb C42A+ and C46), and two open pollinated varieties of pearl millet (Senegal Bulk and RMP-1). Seed was planted in randomized single row plots, 9.1 m in length. Row spacing was 75 cm.

At St. John planting was conducted on 31 May, however, stand establishment was very poor and it was replanted. Stand establishment was again unacceptable and this site was abandoned.

Plots at Hays were harvested 15 October. Yields and number of heads were determined.

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2/ Research Agronomist, USDA, SEA, Kansas State University, Manhattan (ret.).

In addition to the above study, an F_1 diallel yield test was also grown at Hays. In this study, 46 F_1 pearl millet hybrids and various sorghum hybrids were grown in three replications.

Heterosis Study - A study of heterosis was conducted at the Ashland Experiment Field at Manhattan. In this experiment, three female lines of pearl millet, six male lines, and the eighteen crosses from these parents were planted on 5 June in two row plots, 6.1 m in length. Row spacing was 75 cm. After heading average plant height was measured. Additional data taken were: weight of grain harvested, number of heads, and the average head length (of 10 heads selected at random). Thousand seed weights have not yet been determined.

RESULTS AND DISCUSSION

Hybrid Studies - Results of the hybrid yield study at Ashland are shown in Table 1.

Statistical analyses indicate that two pearl millet hybrids, B1 and B2, yielded as well as the DeKalb C42A+ and C46+ sorghum hybrids. Such results are encouraging and point to the high yielding potential of pearl millet hybrids.

Also listed in the table are average plant height, thousand seed weights, average head lengths, and head numbers per hectare. The data indicate that the highest yields are still being obtained by tall hybrids. Since these tall hybrids lodge and make harvesting difficult, plant breeders should reduce plant height while improving grain yields. Millet seed weights are substantially less than those of sorghum, however, it is of interest to note that the highest yielding millet hybrid, B2, had the largest seed weight. In general, the hybrids developed by Burton tended to have higher thousand seed weights than those hybrids developed by Casady. Head lengths showed some variation, however, none were so distinct as to be noteworthy. High yielding millets appear to be typified by a large number of heads per hectare.

Results of the hybrid yield study at Hays are shown in Table 2. Yields of millet hybrids were significantly less than those of sorghum in this experiment. However, results of the diallel study at Hays (shown in Table 3) indicate that a number of pearl millet hybrids yielded as well or better than the sorghum hybrids (DeKalb C42A+, E59, and F67). Admittedly, these sorghums yielded quite poorly compared to those grown at other locations, but it should be noted that the pearl millet hybrids grown at this site were exposed to the same environmental conditions that likely were the cause of these poor sorghum yields.

Heterosis Study - In most of the crosses, hybrid vigor was clearly demonstrated. None of the hybrids yielded lower than their female parent and only one hybrid (4017) yielded lower than its male parent, however, this difference was not significant (Tables 4A and 4B). Fourteen hybrids produced significantly higher yields than both parents. Yields of the four remaining hybrids were not significantly different than those of their higher yielding parent.

In the following table, average results for all female parents, all male parents, and all hybrids are shown.

	Yield (kg/ha)	Height (cm)	Head length (cm)
♀ parents	623	81	15.7
♂ parents	1291	111	17.5
Hybrids	2202	130	20.7

An overall increase in yield due to heterosis is shown. Plant height tended to increase somewhat, though none of the hybrids would be considered excessively tall. A slight increase in head length was also noted.

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Table 1. Hybrid study, Ashland

DMRT grouping*	Hybrid†	Avg yield (kg/ha)	Avg plant height(cm)	Avg 1000 seed wt(gms)	Avg head length(cm)	No. heads thous./ha
A	C42A+	5526	117	18.6	--	100
AB	C46+	4509	126	16.4	--	95
AB	B2	4436	207	9.1	16.7	492
AB	B1	4342	217	7.3	19.3	431
BC	B6	3512	191	6.3	20.3	209
BCD	4039	3453	144	5.2	21.3	280
BCD	4035	3069	145	6.9	19.9	214
CD	B5	3058	133	8.0	23.0	243
CD	B4	3015	141	5.9	19.4	237
CD	4033	2945	143	5.5	20.3	245
CD	4041	2798	135	5.8	19.8	227
CDE	B7	2623	220	8.5	18.8	487
CDE	4023	2616	140	6.1	18.7	186
CDE	4009	2611	145	6.7	19.7	196
CDE	4043	2591	133	6.2	23.3	197
CDEF	4015	2397	145	4.9	20.3	271
CDEF	4045	2235	130	5.5	20.3	202
DEF	4021	2105	126	4.8	19.7	212
DEF	RMP	1885	163	6.3	24.7	202
DEF	4019	1882	134	4.2	22.4	189
EF	B3	1297	139	5.6	17.4	483
F	4013	1187	126	4.0	25.0	240

*DMRT grouping - Duncan's Multiple Range Test grouping for yield. Values with the same letter are not significantly different ($\alpha = .05$).

†B1 through B8 developed by Burton. (B8 destroyed by chinch bugs, not listed.) 4009 through 4045 developed by Casady.

Table 2. Hybrid study, Hays.

DMRT grouping*	Hybrid	Avg Yield (kg/ha)	Number heads thousands/ha
A	C46+	4380	147
A	C42A+	3909	156
B	164	2794	232
BC	309	2108	237
BC	143	2069	184
BC	SEN	2048	234
BC	399	1970	273
BC	95	1865	176
BC	195	1794	170
BC	307	1712	200
BC	174	1667	156
BC	182	1614	309
C	139	1471	228
C	140	1415	199
C	196	1272	186
C	RMP	1164	226

*DMRT grouping - Duncan's Multiple Range Test grouping for yield. Values with the same letter are not significantly different (α = .05).

Table 3. Diallel study, Hays.

DMRT grouping*	Hybrid	Avg yield (kg/ha)	Number heads thousands/ha
A	C42A+	2952	146
AB	1006	2825	224
A-C	1031	2315	254
A-C	1005	2286	250
A-D	1042	2254	237
A-D	1013	2197	282
A-E	1041	2164	240
A-F	1037	2148	213
A-G	1024	2089	171
A-H	1019	1967	205
A-H	1025	1957	277
A-H	1039	1931	275
A-H	1008	1882	231
A-H	1035	1881	227
A-H	1045	1874	202
A-H	1023	1873	233
A-I	E59	1828	105
A-I	1007	1825	237
A-I	1004	1790	177
B-J	1026	1673	195
B-J	1011	1653	255
B-J	1027	1611	179
B-J	1021	1588	252
C-J	1040	1519	174
C-J	1001	1450	215
C-J	1014	1440	224
C-J	1036	1430	213
C-J	1038	1384	249
C-J	1015	1328	161
C-J	1029	1298	156
C-J	1017	1291	198
C-J	1010	1259	215
C-J	1009	1236	241
C-J	1030	1209	158
C-J	1022	1203	212
C-J	1002	1179	224
C-J	1033	1071	237
D-J	1044	988	225
E-J	1046	890	178
E-J	F67	882	84
F-J	1012	856	156
G-J	1032	835	156
H-J	1018	789	185
H-J	1003	784	178
H-J	1028	758	76
IJ	1043	572	154
J	1034	500	188
J	1016	498	125
J	1020	496	148

Table 4A. Heterosis study, Ashland.

Hybrid entry number	Parent or offspring designation
4049	♀ 1
4050	♀ 2 (Female parents)
4051	♀ 3
4053	♂ 1
4054	♂ 2
4055	♂ 3 (Male parents)
4057	♂ 4
4058	♂ 5
4059	♂ 6
	(♀ parent, ♂ parent)
4007	(1 X 1)
4009	(2 X 1)
4011	(3 X 1)
4013	(1 X 2)
4015	(2 X 2)
4017	(3 X 2)
4019	(1 X 3)
4021	(2 X 3) (offspring)
4023	(3 X 3)
4031	(1 X 4)
4033	(2 X 4)
4035	(3 X 4)
4037	(1 X 5)
4039	(2 X 5)
4041	(3 X 5)
4043	(1 X 6)
4045	(2 X 6)
4047	(3 X 6)

Table 4B. Heterosis study, Ashland.

DMRT grouping*	Hybrid entry number	Avg yield (kg/ha)	Avg plant height(cm)	Avg head length(cm)	Number heads thousands/ha
A	4035	3070	136	20.5	249
AB	4021	2905	121	20.0	259
AB	4039	2903	139	20.8	276
AB	4031	2842	145	21.4	248
AB	4033	2774	133	19.3	267
A-C	4023	2629	135	17.4	229
A-D	4009	2426	133	19.6	218
A-D	4019	2403	131	23.0	204
A-D	4041	2387	132	20.3	228
A-D	4043	2334	121	22.7	212
A-D	4011	2329	129	17.7	193
A-D	4047	2328	124	20.3	241
B-E	4045	2061	113	22.3	235
C-F	4015	1903	145	20.3	232
D-F	4057	1799	116	16.5	321
E-G	4037	1499	132	23.3	181
E-H	4059	1399	117	19.3	212
E-H	4058	1366	107	16.1	218
E-H	4007	1359	121	20.6	194
E-H	4053	1325	113	19.9	165
F-I	4055	1158	102	14.3	299
G-I	4050	869	70	15.3	296
G-I	4013	840	130	21.4	204
HI	4054	700	111	19.0	271
HI	4017	648	126	21.6	210
I	4051	531	73	13.8	358
I	4049	470	100	18.1	154

* DMRT grouping - Duncan's Multiple Range Test grouping for yield. Values with the same letter are not significantly different (α = .05).

HERBICIDE SUSCEPTIBILITY OF PEARL MILLET [*Pennisetum americanum* (L.) K. Schum]

W. B. Ndahi, O. G. Russ and M. C. Lundquist

INTRODUCTION

Pearl millet [*Pennisetum americanum* (L.) K. Schum] is a small grain cereal consumed by millions of people in the world, but weeds are a major obstacle to the production of millet (1). Millet, like sorghum, belongs to the grass family and in most parts of the world the two crops are found to grow side by side. It is, therefore, logical that most of the work done on herbicide evaluation for millet has been centered on herbicides that have been found to be tolerated by sorghum. Krishnamurthy (3) found 0.5 kg/ha of 2,4-D (2,4 dichlorophenoxy acetic acid) and 0.5 kg/ha of simazine (2-chloro-4, 6 bis (isopropylamino)-s-triazine to be well tolerated by finger millet (*Eleusine coracana*). In another experiment Jain et al. (2) found atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) and propazine (2-chloro-4,6-bis-isopropylamino-s-triazine) at the rates of 1.5 and 1.0 kg/ha, respectively, to be tolerated by millet. Post emergence application of dimethylamine salt of 2,4-D at the rate of 0.56 kg/ha by Grabousici (1) gave a significantly higher yield in proso millet (*Panicum miliaceum*) than the weedy check.

The objective of this study was to investigate the tolerance of millet to some common sorghum herbicides and also to see whether millet can be killed by Sutan+ and Eradicane.

MATERIALS AND METHODS

After seedbed preparation, all herbicide treatments were applied as preplant incorporated. The herbicide incorporation was 7.5 cm deep. Data were taken on yield, emergence, herbicide injury, plant height, percent maturity, and plant vigor. Emergence, plant vigor, and herbicide injury were scored on a scale from 0-10. The lower the score the better the performance of the herbicide. Percent plant maturity indicates the percentage of mature plants on a given date.

NOTE: Use of product names does not imply endorsement over similar products not named.

Treatments

Treatment	Rate Kg AI/HA
Handweed	---
Atrazine (4F)	2.24
Propazine (80W)	2.68
Bladex (4L)	1.68
Igran (80W)	2.68
Modown (4F)	1.40
Bexton (4L)	3.36
Bexton (4L) + Lorox (50W)	3.36 + 1.12
Bexton (4L) + Modown (4F)	3.36 + 1.40
Bexton/Atrazine (pkg)	4.64
Sutan+ (6.7E)	6.72
Eradicane (6.7E)	6.72

RESULTS AND DISCUSSION

Manhattan and Minneola 1977

Treatment	Manhattan Yield kg/ha	Manhattan Emergence Score	Minneola Yield kg/ha
Handweed	1996	1	951
Atrazine	2105	1	800
Propazine	1986	2	885
Bladex	2159	1	635
Igran	1779	2	980
Modown	2029	2	1021
Bexton	1834	3	911
Bexton + Lorox	2116	1	993
Bexton + Modown	2040	2	910
Bexton/Atrazine	1671	2	861

In 1977 no significant differences were observed among treatments either at Manhattan or Minneola. At Manhattan chinchbug (*Blissus leucopterus*) attack made it necessary to replant all the plots. By the second planting the herbicide activity was reduced considerably. In 1978, the same experiment at Minneola did not provide results because of a severe drought.

Results, Manhattan, 1978

Treatment	Emergence score	July injury score	Plant height cm	Yield kg/ha	August % maturity
Handweed	1	1	136	1440	40
Atrazine	1	2	113	857	30
Propazine	3	3	117	920	30
Bladex	2	2	125	1185	35
Igran	1	2	130	1011	30
Modown	1	1	135	1662	35
Bexton	10	10	83	705*	0
Bexton + Lorox	10	10	87	1000*	0
Bexton + Modown	10	2	85	467*	0
Bexton/Atrazine	10	10	103	922*	0
Sutan+	6	9	87	372	23
Eradicane	10	10	0	0	0
LSD	0.69	1.05	25.7	724.1	10.3

Yield designated by an asterisk refers to treatments that did not allow millet to emerge from the first planting. Yields of these treatments would have been zero had they not been replanted.

DISCUSSION

The emergence score taken on June 12 shows that five treatments, Eradicane, Bexton, Bexton + Lorox, Bexton + Modown and Bexton/Atrazine (pkg) did not allow emergence. On June 27 all plots with the five treatments were replanted.

CONCLUSION

The results obtained show that millet will tolerate the following herbicides: Modown, Cyanazine, Igran, Propazine, and Atrazine. The results also show that all treatments with Bexton (propachlor) did not allow emergence. But replanting after a period of about three weeks did give some yield. Eradicane did not allow emergence after either the first or second planting.

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Seed Vigor Measurements and Their Use in Predicting Field Establishment of Grain Pearl Millet [*Pennisetum americanum* (L.) K. Schum]

G. J. Mwageni and R. L. Vanderlip

It is a common practice to use standard germination results to predict field establishment of a seed lot under field conditions. Standard germination overestimates field establishment (5). Barnes (3) and Vanderlip (5) concluded that prediction of field establishment of a seed lot should be based on the germination results from a stress laboratory test because weaker or non-vigorous seeds would be killed during the harsh treatment and only the vigorous ones would survive.

Seed and seedling vigor are problems in production of grain pearl millet because they affect field establishment, i.e., proper plant populations. This research was conducted to measure vigor in grain millet varieties and to find whether some vigor tests used to evaluate other crops could be applied to pearl millet, and compare those selected vigor tests to find the test that best predicts field establishment of pearl millet.

Materials and Methods

Laboratory and field tests were conducted in 1977 and 1978. The laboratory tests in 1977 included: standard germination, soaking seeds in 2% ammonium chloride solution for 2 hours, artificially aging the seeds at high temperature and relative humidity for 10 days cold test and soaking seeds in 5% sodium hydroxide solution for 2 minutes (1), (2), (3), (4), (5). Immediately after these stress tests, the seeds were germinated under optimum conditions and germination percentages were calculated. Twenty varieties with 50 seeds per seed lot replicated 4 times were used in both field and laboratory tests. In the field, a split plot design was used in which the 3 dates of planting were main plots and the millet varieties were sub-plots. Field establishment was recorded 24 days after planting.

In 1978, the same tests and procedures were used except electrical conductivity of seeds soaked either for 30 minutes or overnight (vigor analyzer) replaced the cold test. A different set of 30 seed lots was used and the number of seeds per treatment was increased to 100. Two locations were included, Manhattan and St. John, where 4 and 2 days of planting were used, respectively. Field establishment counts were recorded 7 and 24 days after planting.

Criteria used to evaluate vigor tests were: 1) correlation with field establishment and 2) ability to rank millet varieties according to field performance.

Results and Discussion

Results of vigor tests of 1977 are summarized in Table 1. The standard germination test had higher laboratory germination percentages

than any of the stress tests. The cold test had the lowest emergence percentages. May 12 and June 7 plantings had lower field establishment because heavy storms destroyed the seedlings before they were counted.

In 1978 standard germination was higher for each seed lot than the stress test (Table 2). NaOH treatment had the lowest germination percentage. Field performance of each seed lot is shown in Table 2. At Manhattan, millet planted on May 2 had the lowest field establishment (average 3%) and the May 30, June 13 field establishment was low because the seedlings were destroyed by a storm. The same happened at St. John.

Analysis of variance indicated that the effects of dates of planting and varieties were highly significant in 1977 and dates, varieties, and the interaction between the two were significant at Manhattan in 1978. At St. John in 1978 only varieties were highly significant and no interaction existed.

Effectiveness of laboratory vigor tests in ranking the millet field establishment (rank means) was used to detect the laboratory vigor test that best predicted field establishment (Barnes, 3). Rank means were determined by subtracting the variety's rank in a particular laboratory test from the field establishment rank, then adding the absolute values of the differences for all varieties and dividing by total number of the varieties. In 1977 standard germination, NH_4Cl and NaOH were almost equal to predict field performance of the millets (Table 4). Cold test was the worst and was discarded in the second year. The 1978 results indicated that NaOH treatment was the closest laboratory stress test to field establishment followed by NH_4CL, accelerated aging, and standard germination (Tables 4 and 5). These results agree with those of Abdullahi (1968), Yayock, et al. (1975), and Barnes (1960) on sorghum.

In 1977, correlations between standard germination, NH_4CL, and NaOH tests were significantly correlated (0.01 level) to field establishment of the 3 dates of planting (Table 6). Correlation between germination following accelerated seed aging and field establishment was significant, (.05). Cold test had the lowest correlation with field establishment.

In 1978 correlation between field establishment of May 30, July 7 plantings and standard germination, NH_4Cl, NaOH and accelerated seed aging were all significant at 1% level for both 7 and 24 day counts (Table 7). The same was true for combined over planting dates. No significant correlations existed between May 2 planting and the laboratory tests. NaOH had the highest number of significant correlations with field establishment followed by the other vigor tests.

Correlations between the 30-minutes soaking (electrical conductivity) procedure and field establishment were negative and insignificant. The overnight soaking was better correlated to field establishment than the 30-minutes soaking procedure.

Field establishment at St. John was not significantly correlated to standard germination for both planting dates but was highly correlated with germination following HaOH treatment (Table 8). NH_4Cl and accelerated aging had mixed results.

Conclusion

Seed vigor is critical for pearl millet field establishment. All the vigor tests used except the cold test and the electrical conductivity were similar in predicting field establishment. NaOH treatment seemed to better predict the field establishment than the other laboratory tests based on the lowest rank means and highest correlations.

Standard germination consistently had higher percentages of germination in each seed lot than those following the stress tests because the nonvigorous seeds were killed during the harsh treatments. The vigorous seeds performed well in both laboratory stress tests and in the field. The opposite was true for nonvigorous seeds.

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Table 1. COMPARATIVE GERMINATION OF PEARL MILLET VARIETIES IN LABORATORY AND FIELD ESTABLISHMENT, 1977

Varieties	May 12 Planting	June 7 Planting	June 29 Planting	Combined over dates (average)	Std. germ.	NH_4Cl	NaOH	Fast Aging	Cold Test (seedling emergence)
	%								
1	38.5	50.0	56.3	47.8	87.5	84.0	66.0	52.5	13.0
2	34.0	37.5	47.5	39.7	81.0	56.5	45.0	24.5	10.0
3	31.5	29.5	62.0	41.0	81.5	71.0	73.0	28.0	16.0
4	37.3	41.5	52.3	43.7	83.0	90.0	68.5	38.5	11.0
5	36.5	34.5	42.3	37.8	61.0	57.0	32.5	31.0	9.0
6	36.0	35.8	49.8	40.5	90.0	89.5	77.5	58.0	15.0
7	34.5	43.5	54.3	44.1	92.5	74.0	64.0	23.0	12.5
8	34.3	43.0	57.8	45.0	85.0	86.0	59.5	28.0	10.0
9	35.0	48.3	55.8	46.3	90.5	69.5	57.0	36.0	49.0
10	32.8	42.8	67.0	47.5	91.0	79.5	59.5	23.0	21.0
11	35.0	28.8	40.5	34.8	69.5	58.5	31.5	13.0	17.5
12	38.3	34.5	46.3	39.7	82.0	74.0	47.0	20.5	18.0
13	15.5	14.0	31.0	20.2	58.0	34.5	18.0	1.0	6.5
14	28.3	30.3	45.0	34.5	81.0	73.5	56.5	16.0	23.0
15	41.5	39.5	56.0	46.0	92.5	87.0	80.0	69.0	34.0
16	33.5	34.5	52.3	40.4	86.5	79.0	47.0	16.0	23.0
17	28.5	28.8	45.5	33.3	85.5	73.5	58.0	33.5	24.5
18	39.8	42.0	64.5	48.8	89.0	90.5	76.5	56.0	17.0
19	25.8	18.3	49.0	31.0	53.0	57.0	4.0	22.5	4.5
20	7.5	9.8	33.5	16.9	46.5	53.5	18.0	26.0	7.0
Average	32.2	34.3	50.4	38.9	79.3	71.9	51.9	30.8	17.1
LSD (.01) Varieties	18.6%	18.6%	18.6%	10.8%	5.6%	7.9%	8.1%	10.3%	10.2%

LSD (.01) for difference between two date means = 15.5%

Table 2. Germination percentages from laboratory millet vigor tests and percentage of field establishment, 1978.

Variety	Standard germ.	Fast aging	NaOH	NH_4Cl	Manhattan							St. John		
					2 May	30 May		13 June		7 July		10 May	30 May	
					24 da.	7 da.	24 da.	7 da.	24 da.	7 da.	24 da.	24 da.	7 da.	24 da.
1	95	81	87	93	7	68	51	46	36	88	75	45	46	42
2	82	76	77	88	5	62	29	36	27	88	74	44	33	24
3	83	67	42	88	1	65	35	26	20	63	49	28	24	18
4	80	77	48	75	7	55	40	36	28	70	60	44	39	32
5	88	66	55	86	1	55	30	33	23	72	62	31	23	19
6	88	70	37	72	4	47	32	27	19	55	48	31	20	16
7	89	62	60	84	1	66	44	47	33	75	64	35	22	16
8	91	76	56	83	2	69	42	48	32	78	64	31	30	21
9	80	62	44	67	2	46	30	32	27	72	58	33	31	25
10	85	46	37	76	1	41	29	29	19	70	58	29	18	15
11	83	60	51	88	2	62	37	32	22	72	58	34	20	18
12	77	76	63	88	5	61	33	28	24	70	58	40	28	21
13	91	77	85	91	5	68	42	42	28	79	52	37	44	30
14	92	63	88	86	3	64	31	29	20	81	54	34	42	30
15	75	43	63	76	6	54	32	47	38	65	52	37	37	29
16	77	56	51	63	0	45	32	28	21	64	53	25	28	21
17	67	44	40	61	3	38	24	32	24	59	48	28	24	20
18	89	66	75	88	2	66	41	41	35	75	59	34	34	26
19	92	81	77	90	3	65	42	41	30	76	64	32	21	15
20	95	86	79	95	3	64	34	35	28	84	72	34	33	28
21	88	64	33	82	1	51	33	24	19	68	52	22	20	15
22	82	81	61	85	6	61	38	43	33	77	64	34	23	18
23	86	47	50	80	1	52	41	38	29	63	51	35	29	23
24	94	82	69	94	1	55	50	41	31	78	68	39	26	19
25	94	72	77	90	0	56	34	27	20	81	65	36	23	17
26	80	62	47	49	0	41	31	24	20	62	53	19	11	9
27	93	59	43	83	1	54	37	38	27	72	57	23	18	15
28	83	41	27	68	3	51	29	36	30	72	59	34	29	23
29	83	43	60	76	2	54	29	43	30	71	62	34	15	12
30	93	78	79	92	1	62	42	43	34	81	66	38	33	24
Average	85.8	65.5	58.7	81.2	3	57	36	36	27	73	59	33	28	21
LSD (.01)	6.8	14.5	14.8	28.1										

Table 3. Rank means of laboratory vigor tests in ranking the 20 millets for field establishment, Manhattan, 1977.

Planting dates	Laboratory Vigor Tests				
	Std. Germ.	NH_4Cl	NaOH	Fast aging	Cold Test
May 12 planting	4.3	3.8	3.9	3.6	5.6
June 7 planting	3.4	3.9	4.4	5.0	5.7
June 29 planting	3.6	3.5	3.2	4.8	5.8
Combined over dates (average field est.)	3.5	3.3	3.4	3.8	5.0
Overall average	3.7	3.6	3.7	4.3	5.5

Table 4. Rank means of laboratory vigor tests in ranking the 30 millets for field establishment, Manhattan, 1978.

Planting dates	Laboratory vigor tests			
	Std. Germ.	NH_4Cl	NaOH	Fast Aging
May 2 planting	10.4	8.8	8.0	7.8
May 30 planting				
7 days	6.5	3.9	5.3	6.5
24 days	7.0	6.1	7.7	6.0
June 13 planting				
7 days	7.7	8.5	7.2	8.8
24 days	9.0	9.0	6.9	8.7
July 7 planting				
7 days	5.1	4.8	4.5	6.3
24 days	7.0	6.3	5.7	6.2
Combined over dates (Average)				
7 days	6.1	4.8	4.4	6.3
24 days	6.4	5.2	5.3	5.8
Overall average	7.2	6.5	6.1	6.9

Table 5. Rank means of laboratory vigor tests in ranking the 30 millets for field establishment, St. John, 1978.

Planting dates	Laboratory vigor tests			
	Std. Germ.	NH_4Cl	NaOH	Fast aging
May 10 planting	8.6	6.5	5.7	7.6
May 30 planting				
a) 7 day count	9.6	8.5	6.3	8.1
b) 24 day count	9.9	8.6	6.7	8.5
Combined over dates (for 24 day count only)	8.8	6.9	5.2	7.8
Overall average	9.2	7.6	6.0	8.0

Table 6. Correlations between pearl millet field establishment and laboratory vigor tests, Manhattan, 1977.

Laboratory seed vigor test	May 12 planting	June 7 planting	June 27 planting	Combined over planting dates (average)
Standard germination	.75**	.85**	.72**	.85**
Germination following NH_4Cl treatment	.69**	.73**	.73**	.77**
Germination following NaOH treatment	.67**	.74**	.69**	.76**
Germination following accelerated seed aging	.53**	.50*	.47*	.54**
Cold test				
i) seedling emergence	.37	.47*	.34	.44
ii) seedling fresh wt	.40*	.51*	.38	.48*
iii) seedling dry wt	.36	.45*	.34	.43

*Significant at 5%
**Significant at 1%

Table 7. Correlations between pearl millet field establishment and laboratory vigor tests, Manhattan, 1978.

Laboratory seed vigor test	May 2 Planting	May 30 Planting		June 13 Planting		July 7 Planting		Combine over planting dates	
	24 day count	7 day count	24 day count	7 day count	24 day count	7 day count	24 day count	7 day count	24 day count
Standard germination	-.13	.61**	.61**	.29	.17	.60**	.50**	.60**	.54**
Germination following NH_4Cl treatment	.20	.84**	.56**	.39*	.30	.69**	.55**	.77**	.60**
Germination following NaOH treatment	.32	.69**	.45**	.44*	.39*	.76**	.57**	.76**	.59**
Germination after fast aging treatment	.34	.64**	.57**	.16	.16	.57**	.56**	.56**	.55**
Germination after ½ hr soaking									
a) /1 All seeds below cut-off point (45 micro amps)	-.08	.17	-.06	-.20	-.22	.22	.11	.09	-.05
b) Only those with high vigor and germinated	.07	.10	-.27	-.32	-.34	-.02	-.13	-.17	.29
Germination following overnight soaking									
a) /1 All seeds below cut-off pt. (60 micro amps)	.42*	.56**	.43*	.31	.24	.44*	.34	.52**	.42*
b) Only those with high vigor and germinated	.25	.39*	.23	-.01	-.06	.39*	.27	.32	.20

* Significant at 5% level

** Significant at 1% level

/1 High vigor according to Vigor analyzer

Table 8. Correlations between pearl millet field establishment and laboratory vigor tests, St. John, Kansas, 1978.

Laboratory seed vigor tests	May 10 planting	May 30 planting		Combined over dates (for 24 days)
	24 day count	7 days	24 days	
Standard germination	.16	.17	.13	.16
Germination following NH_4Cl treatment	.52**	.36*	.32	.45**
Germination following NaOH treatment	.58**	.57**	.49**	.58**
Germination following fast aging	.39*	.31	.27	.35*

* Significant at 5% level.

** Significant at 1% level.

The Effect of Seed Size and Density on Field Emergence and Yield of Pearl Millet [*Pennisetum americanum* (L.) K. Schum.]

J. C. Gardner and R. L. Vanderlip

INTRODUCTION

Pearl millet, [*Pennisetum americanum* (L.) K. Schum.] is grown in the African and Indian tropics, especially in dry and infertile areas where it seems better adapted than other cereal grains. Its ability to overcome drought and other marginal environmental conditions during its growth cycle has been recognized, however, one problem with the crop is seedling establishment. Varieties with improved seed and seedling vigor are being developed, but examination of physical seed characteristics that are related to vigor is needed. Gorg, Kaul, and Singh (2) showed a slight positive correlation between seed size and seed density over 41 varieties of pearl millet although it was statistically insignificant. Maranville and Clegg (3) reported higher percent germination and stand establishment with larger and/or denser sorghum seeds though final grain yield was not significantly affected. These two seed characteristics, size and density, are being studied to determine their effects upon field emergence and grain yield of pearl millet.

MATERIALS AND METHODS

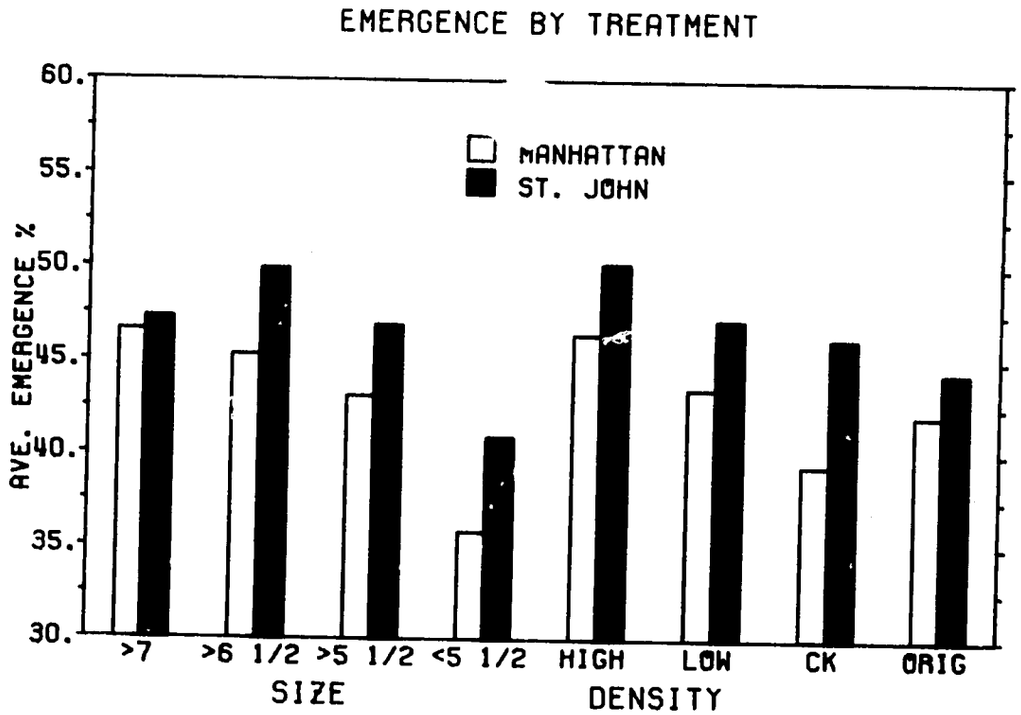
Five varieties of pearl millet were included in the study. Serere 3A, a tall Ugandian variety, and four random mating populations from the Fort Hays Branch Experiment Station breeding program, two tall populations and two with the d_2 dwarfing gene. Four seed sizes, two density fractions, the original seedlot, and a portion of the original seedlot subjected to the same treatment as those seeds separated by density were used. Seeds were sieved through round hole sieves into those that would not pass a 7/64", through a 7/64" but on a 6½/64", through a 6½/64" but on a 5½/64", and those that passed a 5½/64". Density separations were made by placing a portion of the original seedlots in a sucrose solution with a density that resulted in dividing the seedlot approximately in half (3). Density of the solution for each variety to reach this equilibrium varied slightly with an overall average of 1.28. The density fractions and the control were all washed with distilled water and allowed to air dry after the sucrose soak.

All treatments were planted with 50 seeds/row in two row plots, 76 cm between rows and 4.[illegible] meters long. The experiment was a randomized block design, replicated four times, and planted on two dates at Manhattan and St. John, Kansas. Emergence counts were made when the seedlings were between GS-1 and GS-2 (1). This was from 10 to 30 days after planting depending upon planting date. At harvest all mature heads were counted, harvested, and threshed. Yields were corrected to 12.5% moisture and are reported as kg/ha.

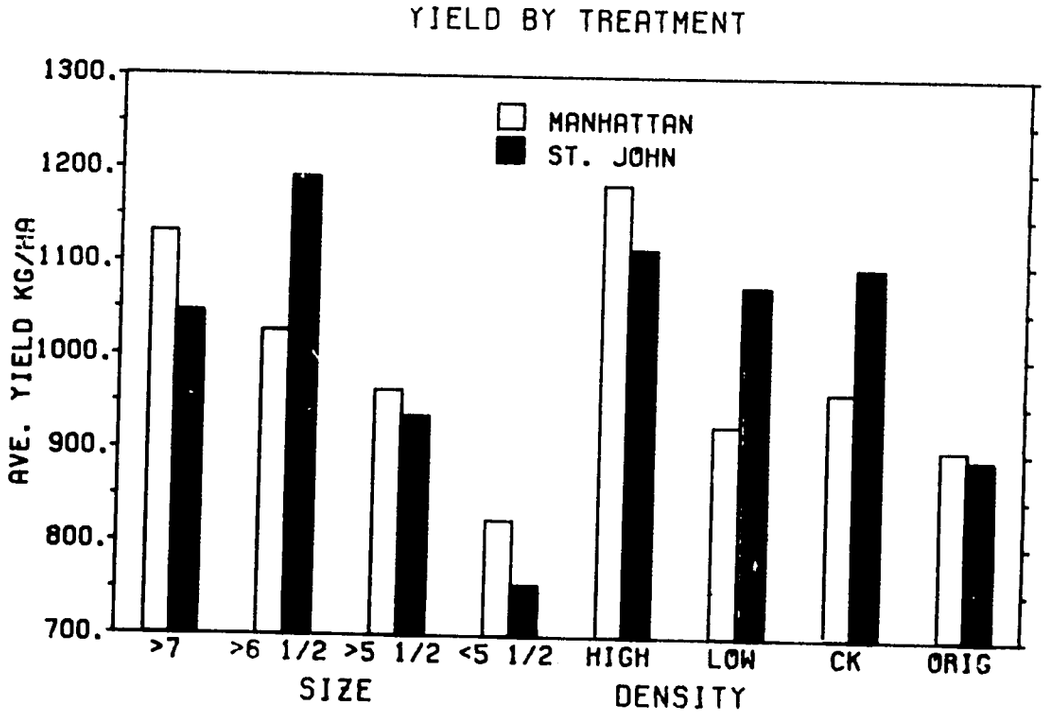
RESULTS AND DISCUSSION

The two locations, Manhattan and St. John, vary in environmental conditions. Rainfall and soil types are the major differences with St. John being the more adverse with a lower rainfall and sandy soils. Field emergence percentages between the five varieties reacted similarly, however, with overall means of 47% at St. John and 43% at Manhattan. Within varieties the treatments reacted much the same between the two locations with the trend being the medium to large seed size and high density seeds producing greater field emergence rates. There was significance at the 1% level at both locations for the treatments of seed size and density combined as they affected emergence of the seedling. The differences in location brought out differing expressions in grain yield between both varieties and treatments. Yields at Manhattan were particularly variable with the lowest yielding variety having a mean yield of 338 kg/ha and the highest 1831 kg/ha, while only 598 kg/ha separated the highest from the lowest yields at St. John. These differences at Manhattan can in part be explained by the high contribution of variability by the second date of planting.

The initial planting was washed over by heavy rains which delayed replanting late into the season. Heavy infestations of chinchbugs moved quickly into the young millet seedlings and the chinchbug showed a preference for the dwarf millets. Along with insects, increased competition for moisture, the shorter growing season, and higher temperatures all combined to show treatment effects. Under stress conditions the higher density seeds performed best followed by the larger seed sizes.



The treatment effect upon yield showed trends like that of field emergence; generally the medium to large seeds and high density seeds yielded more.



This is the first of two years of data which will be collected. For 1979, Serere 3A and two inbred lines of pearl millet were planted in isolation and at flowering given one of three treatments: 1) leaf area was trimmed to reduce photosynthetic production resulting in smaller seeds; 2) the upper one-half of the head was removed to reduce seeds per head resulting in larger seeds; and 3) no treatment. The plantings produced a genetically uniform seedlot with sufficient variability in seed size for the study next year. Use of these narrow genetically based varieties is important to assure that seed sizes or densities is effective within a single genotype and is not a sorting of genotypes which could be responsible for the effects on yield and field emergence rates.

Conclusions from one year of data showed the small seed size is definitely inferior in emergence and yield performance as compared to the two largest sizes. The planting of seeds greater than 6½/64" in size, or, with a density greater than 1.28 will increase field emergence by 5% and yield from 200 to 300 kg/ha as compared to the planting of the original seedlots.

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Drought Resistance Screening of Pearl Millet [*Pennisetum americanum* (L.) K. Schum]

P. Singh and E. T. Kanemasu

INTRODUCTION

Pearl millet, *Pennisetum americanum* (L.) K. Schum, is primarily grown in areas and in periods of low precipitation. It is recognized as one of the most drought resistant cereals (Singh, Datta, Singh, 1971). However, its drought resistant characteristics are not well known and documented.

Our primary objective is to investigate the water use and drought resistant characteristics of pearl millet.

METHODS AND MATERIALS

Research plots were established at the Ft. Hays Branch Experiment Station and at Manhattan Agronomy Farm during the 1978 growing season. The cultivars used were Senegal Bulk, HMP-1700, RMP-1(5)C, Tall Bulk, Serere-3A, and HMP-600. The plots were composed of 4 - 76 cm rows (center to center) and 10 m in length.

At Hays, leaf and air temperatures were measured with fine thermocouples and recorded every hour on a portable data acquisition system (Campbell Inst.). Soil moisture was measured at three times with a neutron attenuation meter. The soil is silty clay loam with maximum water holding capacity of about 10 inches.

At Manhattan, leaf and air temperatures were measured with thermocouples and infrared thermometer. Leaf area, dry weight, growth stage and soil moisture were determined weekly. Stomatal resistance and xylem potential were estimated by stomatal diffusion porometer (Delta-T Devices) and pressure bomb, respectively. The soil is a fine silty clay loam with maximum water holding capacity of about 12 inches.

RESULTS AND DISCUSSION

Hays results.

Analysis of these data are not complete and results will be available at a later date.

Manhattan results.

Development. Two plantings were made -- the first on 25 May and the other on 26 June. Growth stages of both plantings were recorded according to the identifying features of Table 1. Not all the growth stages were obtained (Table 2). In general, development stages are delayed when compared with those grown in India (Table 3). This is probably due to the longer photoperiod (14 hours) in June and July at Manhattan.

Plants were brought into the laboratory and dissected. Leaves and tillers were counted. The apex was prepared for examination under the scanning electron microscope (SEM). A detail account of the panicle development using SEM will be presented at a later date.

Water Use. Total amounts of water used by the genotypes were not too different -- about 38 cm (Table 4). This is much greater water use than those in India (Table 5); however, grain yields were about three times greater (Table 7).

Dry matter in Table 6 are the leaf area indices (LAI) and dry weights per plant (average of three plants) taken throughout the season on both first and second plantings. The individual plants varied widely due to difference in number of tillers. This is reflected in the temporal trends which vary in an irregular manner. An improved sampling scheme will be incorporated in the future. It appears that tillers and main culm data need to be separated.

Yield. Shown in Tables 7 and 8 are the grain yield for the first and second plantings. Senegal Bulk and Serere-3A yielded high on both plantings while HMP-1700 ranked the highest on the 1st planting but last on the 2nd planting. In general, the yields did not follow the seed weights; however, the highest yielding genotype, Serere-3A had the largest seed (Table 9). There did not appear to be statistical difference in seed weight at different locations along the head (Table 10).

Leaf temperature. In Fig. 1 and 2 are the leaf and air temperatures for the millet genotypes on a typical day. Soil water availability was not limiting at this time. Leaf temperatures among the genotypes varied widely after midday. The ranking of genotype by leaf temperature from high to low are as follows: HMP-1700, Senegal Bulk, Tall bulk, HMP-600, RMP-1(5)C, and Serere-3A. We have hypothesized that those with the highest leaf temperature are the highest grain yielding; however, the lowest temperature genotypes were not the lowest yielding. The total dry matter accumulations (Table 6b) at the latter part of the growing season are ranked as follows (high to low); Senegal Bulk, HMP-1700, HMP-600, Tall bulk, RMP-1(5)C, and Serere-3A. This ranking corresponds very well with the leaf temperature ranking.

Table 1. Growth stages of millet.

Growth Stage	Identifying Characteristic
0	Emergence
1	Collar of third leaf visible
2	Collar of fifth leaf visible
3	Growing point differentiation
4	Final leaf visible
5	Boot- Head extended into flag leaf sheath
6	Half bloom
7	Soft dough
8	Hard dough
9	Physiological maturity

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Table 2. Days after emergence for growth stage of 1st and 2nd planting of pearl millet at Manhattan, Kansas.

1st Planting (25 May, 1978)

Growth Stage	HMD 600	Serere 3A	Tall Bulk	RMP-1(5)C	HMP 1700	Senegal Bulk
0	0	0	0	0	0	0
1	7	7	7	7	7	7
2						
3	28	28	33	28	28	28
4						
5	43	43	56	46	43	43
6	60	60	70	60	55	55
7	77	77	82	77	60	60
8					77	77
9						
Harvest	82	82	92	82	82	82

2nd Planting (26 June, 1978)

Growth Stage						
0	0	0	0	0	0	0
1						
2						
3						
4			47	47		
5	47	47	59	50	47	40
6	55	55	66	59	55	47
7	66	66	82	66	66	66
8						
9						
Harvest	95	95	95	90	90	90

Table 3. Days after emergence for the various growth stages of pearl millet grown in India, and Nigeria.

Growth Stage	HB3[1/]	Mel Zengo[1/]	Gero[2/]	BK560[3/]
0	0	0	0	0
1	6	6		
2	14	15		
3	22	28	28	
4		43		
5	35	47	49	36
6	40	53	59	39
7	54	63		
8	58	69		
9	65	75		
Harvest			90	82

[1/] Alagarswamy, Maiti and Bidinger. 1977. (India)

[2/] Kassan and Kowal. 1975 (Samaru, Nigeria)

[3/] Gregory and Squire. 1978. (India - Rabi Season)

Table 4. Water use (cm) of millet from planting until physiological maturity.

	1st Planting	2nd Planting
HMP 1700	37.6	32.7
Senegal Bulk	36.2	37.3
HMP 600	37.2	35.2
Serere - 3A	37.6	35.8
RMP-1(5)C	36.7	30.1
Tall Bulk	41.8	36.0

Table 5. Water use and grain yield of millet taken from the literature.

	Seasonal ET	Yield
	cm	kg / HA
Senegal 1/	9	537
RMP1 1/	11.3	575
Gero 2/	33.0	3,828
BK 560 3/ (approximated)	11.0	1,580

1/ Wendt, C. 1978. personal communication.

2/ Kassan and Kowal. 1975.

3/ Gregory and Squire. 1978.

Field observations on the growth and physiology of Pearl Millet at ICRISAT. Preliminary results. University of Nottingham, England.

Table 6a. Dry Matter Production (gms/plant) in First Planting

Date	Genotype	Total Dry Wt.	Stem Dry Wt.	Leaves Dry Wt.	Heads Dry Wt.	LAI
June 21	HMP-600	12.13	8.73	3.4		.76
	Serere -- 3A	20.08	13.43	6.65		1.41
	Tall Bulk	24.52	19.12	5.40		1.25
	RMP-1(5)C	12.35	7.73	4.62		0.96
	HMP-1700	14.72	10.47	4.25		0.75
	Senegal Bulk	29.27	21.7	7.57		1.62
26	HMP-600	8.31	3.59	4.72		1.11
	Serere - 3A	8.36	3.73	4.63		1.30
	Tall Bulk	6.1	2.65	3.45		0.77
	RMP-1(5)C	12.76	5.72	7.04		2.06
	HMP-1700	8.00	3.42	4.58		1.03
	Senegal Bulk	11.14	4.90	6.24		1.61
29	HMP-600	5.39	3.53	1.86		0.5
	Serere - 3A	20.91	11.82	9.09		1.56
	Tall Bulk	23.95	20.17	3.78		.92
	RMP-1(5)C	.21.92	11.23	10.69		1.89
	HMP-1700	15.06	7.60	7.46		1.22
	Senegal Bulk	40.32	21.95	18.37		2.61
July 3	HMP-600	31.54	15.6	15.94		3.55
	Serere - 3A	37.88	16.00	21.88		4.96
	Tall Bulk	17.89	8.94	8.95		1.77
	RMP-1(5)C	12.6	6.67	5.93		1.39
	HMP-1700	16.32	8.06	8.26		1.83
	Senegal Bulk	46.34	22.47	23.87		5.12
7	HMP-600	57.8	27.69	30.11		4.8
	Serere - 3A	124.91	64.59	60.32		12.54
	Tall Bulk	50.12	22.62	27.50		5.25
	RMP-1(5)C	63.21	29.00	34.21		4.78
	HMP-1700	65.28	29.01	36.27		7.69
	Senegal Bulk	69.03	32.37	36.66		7.53
July 10	HMP-600	33.19	17.06	16.13		4.06
	Serere - 3A	22.78	12.21	10.57		2.91
	Tall Bulk	71.6	35.80	35.80		7.45
	RMP-1(5)C	76.98	42.43	34.55		9.42
	HMP-1700	51.98	28.84	23.14		4.37
	Senegal Bulk	89.57	50.10	39.47		9.19
14	HMP-600	33.64	18.91	14.73		3.98
	Serere - 3A	42.38	25.00	17.38		3.86
	Tall Bulk	109.76	55.53	54.23		8.88
	RMP-1(5)C	152.75	67.27	85.48		-
	HMP-1700	20.41	9.59	10.82		2.12
	Senegal Bulk	72.48	38.94	33.54		3.51
17	HMP-600	45.03	23.8	21.23		2.45
	Serere - 3A	113.49	70.63	42.86		8.81
	Tall Bulk	102.25	63.00	39.25		5.59
	RMP-1(5)C	112.46	68.84	43.62		7.59
	HMP-1700	72.46	47.31	25.15		4.53
	Senegal Bulk	59.74	42.72	17.02		5.88

Table 6a (cont.)

Date		Genotype	Total Dry Wt.	Stem Dry Wt.	Leaves Dry Wt.	Heads Dry Wt.	LAI
July	20	HMP-600	55.92	39.62	16.30		6.27
		Serere - 3A	197.35	54.47	142.88		7.39
		Tall Bulk	104.5	60.07	44.43		7.65
		RMP-1(5)C	44.32	19.28	25.04		10.35
		HMP-1700	44.84	18.12	26.72		-
		Senegal Bulk	42.6	25.63	16.97		-
	24	HMP-600	177.02	112.17	45.65	19.20	7.00
		Serere - 3A	174.25	107.15	38.90	28.20	5.00
		Tall Bulk	115.08	87.54	27.54	-	4.63
		RMP-1(5)C	72.13	39.53	27.41	5.19	5.86
		HMP-1700	128.86	75.31	41.63	11.92	7.00
		Senegal Bulk	83.92	50.86	19.86	13.20	3.74
	27	HMP-600	97.49	58.60	26.00	12.89	3.36
		Serere - 3A	248.48	164.00	49.80	34.68	5.80
		Tall Bulk	147.73	114.09	30.89	2.75	3.59
		RMP-1(5)C	147.78	87.22	57.14	3.42	7.80
		HMP-1700	79.61	35.33	32.42	11.86	4.91
		Senegal Bulk	365.1	252.34	66.13	46.63	9.28
August	4	HMP-600	166.18	95.89	33.16	37.13	4.45
		Serere - 3A	189.51	110.82	37.17	41.52	5.86
		Tall Bulk	261.78	184.82	76.96	-	12.03
		RMP-1(5)C	114.1	45.27	40.52	28.31	8.27
		HMP-1700	111.24	41.86	36.44	32.94	6.34
		Senegal Bulk	128.88	41.59	28.44	58.85	5.46
	8	HMP-600	211.84	93.68	33.68	84.48	4.96
		Serere - 3A	185.09	99.12	40.04	45.93	6.66
		Tall Bulk	112.96	75.00	34.28	3.68	5.02
		RMP-1(5)C	240.63	103.76	70.52	66.35	11.55
		HMP-1700	142.48	63.40	37.54	41.54	6.01
		Senegal Bulk	191.00	71.28	24.72	95.00	3.15
	10	HMP-600	289.61	78.58	45.44	165.59	7.51
		Serere - 3A	148.08	81.16	27.34	39.58	5.54
		Tall Bulk	325.54	264.54	61.00	-	9.01
		RMP-1(5)C	184.89	67.33	55.95	61.61	8.21
		HMP-1700	277.41	76.64	52.56	148.21	8.06
		Senegal Bulk	183.41	80.92	39.48	63.01	7.32
	15	HMP-600	109.53	48.14	24.23	37.16	4.07
		Serere - 3A	130.21	52.27	22.88	55.06	4.40
		Tall Bulk	119.3	67.78	51.52	-	8.02
		RMP-1(5)C	109.63	43.68	12.13	53.82	2.18
		HMP-1700	243.17	51.29	52.12	139.76	7.56
		Senegal Bulk	338.21	100.30	51.57	186.34	9.32

Table 6b. Dry Matter Production (gms/plant) in Second Planting

Date	Genotype	Total Dry Wt.	Stem Dry Weight	Leaves Dry Wt.	Heads Dry Wt.	LAI
July 27	HMP-600	9.23	4.0	5.23		.80
	Serere - 3A	15.67	7.06	8.61		1.22
	Tall Bulk	5.76	2.86	2.90		.56
	RMP-1(5)C	10.18	4.51	5.67		1.16
	HMP-1700	4.12	1.59	2.53		.38
	Senegal Bulk	5.61	2.33	3.28		.73
August 2	HMP-600	21.42	13.94	7.48		1.08
	Serere - 3A	14.79	6.38	8.41		2.03
	Tall Bulk	19.62	10.79	8.83		2.04
	RMP-1(5)C	4.77	2.52	2.25		.54
	HMP-1700	-	-	-		.55
	Senegal Bulk	31.81	13.08	18.73		3.96
4	HMP-600	24.36	11.28	13.08		2.17
	Serere - 3A	22.69	11.45	11.24		2.64
	Talk Bulk	18.47	9.40	9.07		2.27
	RMP-1(5)C	11.24	5.42	5.82		1.23
	HMP-1700	8.08	3.96	4.12		.70
	Senegal Bulk	18.0	7.8	10.20		2.36
8	HMP-600	11.53	5.89	5.64		.88
	Serere - 3A	45.28	19.64	25.64		5.55
	Tall Bulk	36.29	16.00	20.29		3.50
	RMP-1(5)C	31.87	15.26	16.61		2.91
	HMP-1700	38.82	13.95	24.87		3.75
	Senegal Bulk	33.45	15.10	17.77	0.58	3.62
10	HMP-600	60.8	33.50	27.30		4.08
	Serere - 3A	49.58	31.18	18.40		3.24
	Tall Bulk	142.46	84.00	58.46		2.72
	RMP-1(5)C	28.7	16.36	12.34		2.10
	HMP-1700	35.29	17.27	18.02		2.14
	Senegal Bulk	106.39	48.98	36.26	21.15	4.84
August 15	HMP-600	31.38	20.9	10.84		1.62
	Serere - 3A	109.59	70.84	38.75		7.71
	Tall Bulk	28.31	14.02	14.29		2.58
	RMP-1(5)C	35.77	21.31	14.46		2.61
	HMP-1700	71.59	36.50	35.09		4.76
	Senegal Bulk	60.57	30.88	22.84	6.85	4.30
August 17	HMP-600	78.01	58.34	18.74	0.93	2.5
	Serere - 3A	58.73	42.98	15.75		2.59
	Tall Bulk	30.83	16.46	14.37		2.80
	RMP-1(5)C	51.61	30.15	21.46		3.29
	HMP-1700	22.71	8.31	14.40		2.04
	Senegal Bulk	24.53	10.73	9.96	3.84	1.73
August 20	HMP-600	27.47	14.70	8.78	3.99	1.03
	Serere - 3A	53.31	29.11	17.36	6.84	2.43
	Tall Bulk	29.01	14.76	14.25		7.81
	RMP-1(5)C	76.64	42.31	34.33		4.15
	HMP-1700	51.94	27.27	20.49	4.18	1.37
	Senegal Bulk	120.42	48.68	54.79	16.95	10.05

Table 6b. (cont.)

Date		Genotype	Total Dry Wt.	Stem Dry Weight	Leaves Dry Wt.	Heads Dry Wt.	LAI
August	29	HMP-600	120.9	50.79	32.86	36.44	4.09
		Serere - 3A	279.26	173.75	34.45	71.06	4.69
		Tall Bulk	225.13	168.35	48.68	8.10	6.84
		RMP-1(5)C	85.4	52.48	24.85	8.07	3.01
		HMP-1700	106.61	53.46	37.21	15.94	3.00
		Senegal Bulk	126.07	60.75	26.81	38.51	3.78
Sept.	7	HMP-600	89.78	36.34	30.52	22.92	1.67
		Serere - 3A	131.59	67.61	21.90	42.08	1.87
		Tall Bulk	124.23	76.65	28.85	18.73	3.48
		RMP-1(5)C	59.51	26.63	24.78	8.10	2.65
		HMP-1700	42.03	11.22	14.08	16.73	.93
		Senegal Bulk	293.59	97.40	79.45	116.74	8.84
	18	HMP-600	160.65	45.42	32.45	82.78	2.22
		Serere - 3A	408.66	218.09	56.16	134.41	4.75
		Tall Bulk	528.69	340.34	75.92	112.43	5.47
		RMP-1(5)C	62.19	27.68	26.33	8.18	2.46
		HMP-1700	103.55	27.37	24.38	51.80	0.98
		Senegal Bulk	213.71	55.39	38.44	119.88	3.38

Table 7. Grain Yields (Kg/Ha) in First Planting of Various Genotypes of Millet.

Replications	HMP-600	Serere - 3A	Tall Bulk	RMP-1(5)C	HMP-1700	Senegal Bu
	Genotypes					
1	2694	2226	1266	1989	4245	3576
2	1971	2956	941	2543	4428	4128
3	1893	3887	2826	2834	4686	4166
4	1273	3107	2027	2846	4126	4123
Mean	1958	3044	1765	2553	4371	3998

$LSD_{(.05)}$ for means = 751

Ranking of Yields

HMP-1700	Senegal Bulk	Serere - 3A	RMP-1(5)C	HMP-600	Tall Bulk
4371	3998	3044	2553	1958	1765

Table 8. Grain Yield (Kg/Ha) of Various Genotypes of Millet in Second Planting.

Replications	HMP-600	Serere - 3A	Tall Bulk	RMP-1(5)C	HMP-1700	Senegal Bulk
	Genotypes					
1	486	787	648	1068	197	1424
2	1474	1304	846	326	669	1682
3	465	1240	859	732	192	1205
4	690	2073	722	528	395	729
Means	779	1351	769	663	363	1260

$LSD_{(.05)}$ for means = 577

Ranking of means:

Serere - 3A	Senegal Bulk	HMP-600	Tall Bulk	RMP-1(5)C	HMP-1700
1351	1260	779	769	663	363

Table 9. Average 500 Seed Weight (in gms) of Various Millet Genotypes.

	Millet Genotypes						
Plantings	HMP-600	Serere-3A	Tall Bulk	RMP-1(5)C	HMP-1700	Senegal Bulk	LSD (.05)
First	6.045	6.199	4.423	3.848	4.631	5.502	1.228
Second	4.672	5.266	3.839	3.783	3.573	4.634	0.273

Table 10. Variation in 500 Seed Weight (in gms) in Different Parts of Earheads of Millet Genetypes.

Genotype	Top 1/3	Middle 1/3	Bottom 1/3	LSD
HMP-600	6.178	5.829	6.128	NS
Serere - 3A	6.023	6.286	6.289	NS
Tall Bulk	4.155	4.570	4.543	NS
RMP-1(5)C	3.842	3.970	3.732	NS
HMP-1700	4.581	4.464	4.849	NS
Senegal Bulk	5.682	5.292	5.533	NS

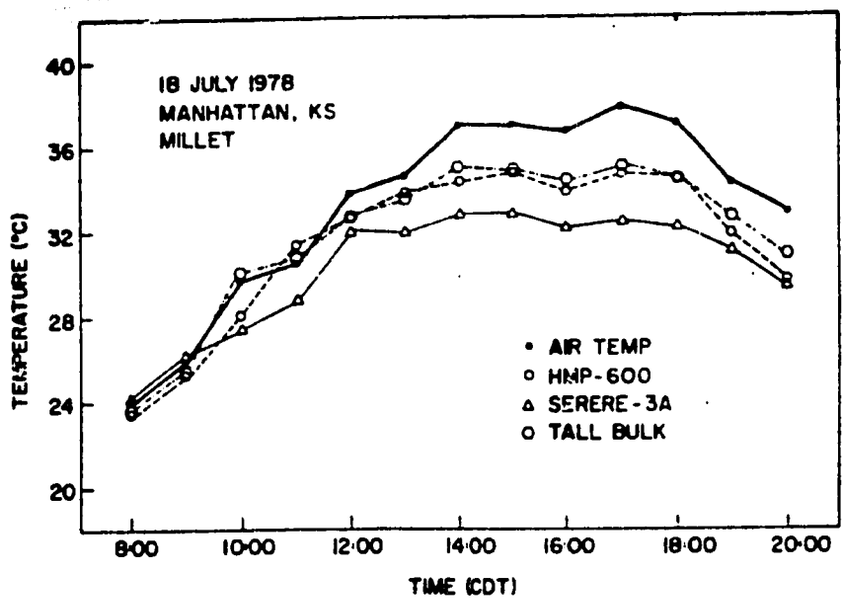

Fig. 1 Leaf and air temperatures of HMP-600, Serere-3A, and Tall Bulk on July 18, 1978

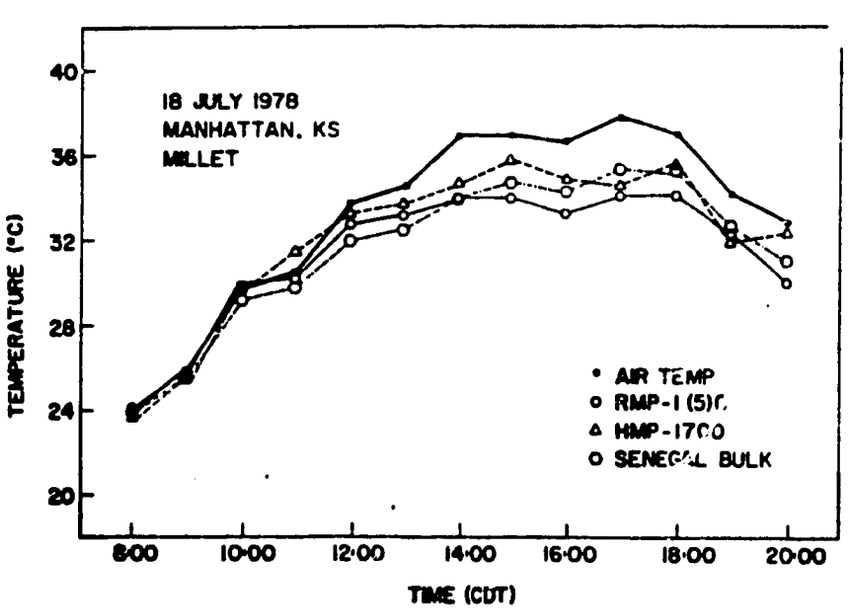

Fig. 2 Leaf and air temperatures of RMP-1(5)C, HMP-1700, and Senegal Bulk on 18 July, 1978.

Objective 3. "Determine the nutritional quality and digestibility of pearl millet grain by analyzing protein in germplasm introductions and breeding materials and determining magnitudes of variation in lysine concontent among and within populations and varieties. Determine the characteristics and digestibility of pearl millet protein and carbohydrates."

General Introduction

A study of the "quality" differences among cultivars of pearl millet encompasses an investigation into: (1) the nutrient content of the grain, (2) the biochemical and functional characteristics of the major components of the grain and how they affect end-use properties, and (3) the biological availability of major nutritional components.

NUTRIENT CONTENT OF PEARL MILLET

E. Varriano-Marston, R. C. Hoseney and Y. F. Yeh Chung

Proximate Analysis

Crude protein, ash and moisture determinations were run on 4 bulk populations and 17 HMP 550 S_1 lines. The results are presented in Table 1. The range of protein content is narrow: 11.1% to 14.1% on a 14% moisture basis.

Amino Acid Analysis

Amino acid analysis of the millet meal was completed, and the results for the various cultivars are shown in Table 2-5. These data show that: (1) the limiting amino acids are lysine and methionine, (2) considerable variability exists among lines and populations with respect to lysine content, and (3) the leucine:isoleucine ratio remains fairly constant across cultivars.

Minerals in Pearl Millet

Elemental analysis of pearl millet cultivars by atomic absorption and flame emission indicated that (1) K and Mg are the major elements in the grain, (2) millet contains more Fe and Na than wheat, (3) the HMP 550 population and S_1 lines contain higher K levels than wheat, (4) the Ca content of millet is lower than that reported for wheat, and (5) there is some variability in mineral content among cultivars (Table 6).

Phosphorus as P_2O_5 was also determined in pearl millet cultivars. These values are shown in Table 7. There appears to be a narrow range of phosphorus in millet and these values are twice the level reported for whole wheat flour (Agric. Handbook #8).

Plans are being made to study the phytic acid content of pearl millet cultivars since this component may affect the absorption and availability of minerals in animals and humans.

Vitamins

Analysis of the riboflavin content in pearl millet (Table 8) showed that there was little variability in this vitamin among cultivars. Pearl millet does, however, contain significantly higher riboflavin levels than wheat.

Attempts have been made to determine thiamine in millet but some difficulties were encountered in purification. Therefore, a column purification procedure will be investigated. Niacin will be determined by standard cereal analysis techniques.

Table 1. Proximate Analysis of Pearl Millet Cultivars

Sample	Protein (%)	Moisture (%)	Ash (%)
*RMPI(S)CI[a]	11.1	14.2	1.4
*HMP1700[b]	14.7	10.4	1.6
*Serere 3A[b]	13.5	9.5	1.6
*HMP550[b]	13.6	9.6	1.8
HMP550 S_1 LINES			
114	13.9	10.8	1.7
120	13.3	10.5	1.8
134	13.5	10.7	1.8
149	13.0	10.4	1.9
155	13.5	10.6	1.9
160	13.0	7.8	1.9
179	13.5	10.7	1.7
180	14.0	10.9	1.7
189	13.0	11.0	1.7
191	13.6	10.8	1.9
193	13.8	10.5	1.8
196	13.8	11.0	1.7
200	13.9	10.5	1.8
201	14.1	10.6	1.9
218	13.3	10.7	1.8
220	12.8	10.0	1.6
240	13.8	9.9	1.8

*Bulk populations

[a]1976, Manhattan, KS

[b]1977, Hays, KS

TABLE 2

DEPARTMENT OF GRAIN SCIENCE AND INDUSTRY - KANSAS STATE UNIVERSITY

AMINO ACID ANALYSIS

GRAMS OF AMINO ACIDS PER 100G PROTEIN CORRECTED TO 100% RECOVERY PROTEIN BASIS

	HMP 550/Bulk	HMP1700	Serere 3A	RMPI(S)CI
Lysine	2.8	3.1	3.2	3.2
Histidine	2.1	2.1	2.0	2.0
Ammonia	3.3	3.3	3.3	2.6
Arginine	3.8	3.5	3.2	5.0
Aspartic Acid	9.7	10.1	10.3	9.2
Threonine	3.8	4.0	4.1	4.1
Serine	5.5	5.8	5.8	5.7
Glutamic Acid	21.5	21.4	21.5	20.8
Proline	7.2	6.8	7.0	7.3
Half Cystine	0.6	0.5	0.4	0.8
Glycine	3.7	3.8	3.5	4.4
Alanine	9.1	9.1	8.8	8.6
Valine	4.0	4.1	4.0	3.9
Methionine	1.9	1.9	1.9	2.2
Isoleucine	3.2	3.2	3.3	3.1
Leucine	10.1	10.1	10.2	9.5
Tyrosine	2.7	2.6	2.6	2.8
Phenylalanine	4.7	4.6	4.6	4.5
Protein	13.6	14.7	13.5	11.1
Moisture	9.6	10.4	9.5	14.2

TABLE 3

DEPARTMENT OF GRAIN SCIENCE AND INDUSTRY - KANSAS STATE UNIVERSITY

AMINO ACID ANALYSIS

GRAMS OF AMINO ACIDS PER 100G PROTEIN CORRECTED TO 100% RECOVERY PROTEIN BASI

	HMP 550 S_1 LINES				
	155	114	120	134	149
Lysine	2.8	3.0	2.9	2.8	3.1
Histidine	1.9	2.1	2.1	1.9	2.1
Ammonia	3.3	3.1	3.1	3.3	3.1
Arginine	4.6	4.9	4.2	4.7	5.3
Aspartic Acid	9.6	9.8	9.9	9.9	9.4
Threonine	4.0	3.9	3.9	3.9	3.9
Serine	5.6	5.7	5.4	5.5	5.5
Glutamic Acid	21.3	21.4	22.3	20.9	20.7
Proline	7.9	7.3	7.6	7.3	8.1
Half Cystine	0.4	0.6	0.5	0.6	0.5
Glycine	3.7	3.9	3.7	3.7	3.8
Alanine	9.0	8.7	8.7	8.8	8.6
Valine	4.0	3.9	3.8	4.1	3.9
Methionine	1.7	1.9	2.0	2.1	1.7
Isoleucine	3.5	3.1	3.1	3.2	3.3
Leucine	9.0	9.7	9.7	9.8	9.6
Tyrosine	2.8	2.5	2.6	2.8	2.7
Phenylalanine	4.7	4.5	4.5	4.7	4.6
Protein	13.5	13.9	13.3	13.5	13.0
Moisture	10.6	10.8	10.5	10.7	10.4

TABLE 4

DEPARTMENT OF GRAIN SCIENCE AND INDUSTRY - KANSAS STATE UNIVERSITY

AMINO ACID ANALYSIS

GRAMS OF AMINO ACIDS PER 100 G PROTEIN CORRECTED TO 100% RECOVERY PROTEIN BASIS

	HMP 550 S_1 LINES					
	160	179	180	189	191	193
Lysine	3.0	2.8	2.5	2.7	2.8	2.7
Histidine	2.1	2.1	2.0	2.2	2.1	1.7
Ammonia	3.2	3.1	3.2	3.2	3.1	3.2
Arginine	4.4	4.5	4.3	4.4	4.6	4.1
Aspartic Acid	9.3	8.8	9.6	9.7	9.7	10.1
Threonine	3.9	3.9	3.8	3.7	3.8	3.9
Serine	5.9	5.5	5.5	5.7	5.5	5.9
Glutamic Acid	21.3	22.2	22.1	21.9	21.5	21.2
Proline	7.7	7.9	8.0	7.8	8.0	8.1
Half Cystine	0.7	0.6	0.6	0.6	0.6	0.6
Glycine	3.0	3.3	3.3	3.5	3.7	3.5
Alanine	8.7	8.9	8.8	8.6	8.5	8.7
Valine	3.9	3.9	3.9	3.8	3.7	3.8
Methionine	2.1	2.0	1.9	1.9	2.1	2.0
Isoleucine	3.3	3.2	3.2	3.2	3.1	3.1
Leucine	10.0	10.1	10.0	9.8	9.8	10.0
Tyrosine	2.7	2.6	2.6	2.5	2.7	2.6
Phenylalanine	4.7	4.5	4.6	4.5	4.6	4.7
Protein	13.0	13.5	14.0	13.0	13.6	13.8
Moisture	7.8	10.7	10.9	11.0	10.8	10.5

TABLE 5

DEPARTMENT OF GRAIN SCIENCE AND INDUSTRY - KANSAS STATE UNIVERSITY

AMINO ACID ANALYSIS

GRAMS OF AMINO ACIDS PER 100G PROTEIN CORRECTED TO 100% RECOVERY PROTEIN BASIS

	HMP 550 S_1 LINES					
	196	200	201	218	220	240
Lysine	2.9	2.8	2.496	3.1	3.0	2.7
Histidine	1.9	2.1	2.0	2.1	2.1	1.9
Ammonia	3.1	3.1	3.250	3.4	3.0	3.1
Arginine	4.8	4.6	4.696	4.9	4.7	4.1
Aspartic Acid	9.8	9.7	9.456	9.9	9.5	9.5
Threonine	3.9	3.7	3.9	4.0	4.0	3.9
Serine	5.6	5.5	5.8	5.7	5.8	5.8
Glutamic Acid	21.0	21.9	21.9	20.9	21.1	22.9
Proline	8.2	8.2	7.1	7.2	6.7	7.0
Half Cystine	0.5	0.5	0.6	0.5	0.6	0.5
Glycine	3.7	3.5	3.5	3.7	3.8	3.5
Alanine	8.6	8.6	8.6	8.6	9.0	8.9
Valine	3.9	3.8	3.9	3.9	4.0	3.8
Methionine	1.8	1.9	2.1	2.0	2.1	2.0
Isoleucine	3.5	3.2	3.2	3.1	3.3	3.1
Leucine	9.7	9.8	10.0	9.6	9.8	10.2
Tyrosine	2.7	2.5	2.7	2.6	2.7	2.5
Phenylalanine	4.7	4.6	4.8	4.8	4.7	4.6
Protein	13.8	13.9	14.1	13.3	12.8	13.8
Moisture	11.0	10.5	10.6	10.7	10.0	9.9

TABLE 6. Minerals in Pearl Millet (μg/g)

	Ca	Mg	Zn	Fe	Na	K
RMPI(S)CI	99	1167	38	73	45	3660
HMP1700	132	1330	31	61	43	3864
Serere 3A	126	1384	30	78	41	3679
HMP550	89	1389	28	79	45	4605
HMP550 S_1 LINES:						
240	98	1346	29	74	44	4224
220	116	1364	30	81	45	4037
218	76	1557	34	78	42	4203
201	84	1512	30	74	43	4657
200	79	1382	27	70	40	4605
191	92	1460	26	74	34	4954
189	81	1374	29	78	39	4643
180	65	1499	28	70	46	4628
160	109	1432	26	74	43	4808
155	79	1358	28	77	22	4876
134	74	1488	34	83	48	4471
120	112	1318	23	69	49	4993
114	81	1399	34	83	45	4524
179	96	1507	28	79	43	5106
149	122	1450	27	68	20	4436

TABLE 7. Phosphorus as (P_2O_5) in Pearl Millet

Sample	%
*RMP 1(S)C1	0.665 ± 0.029
*HMP1700	0.748 ± 0.015
*HMP550	0.864 ± 0.021
*Serere 3A	0.794 ± 0.022
240	0.761 ± 0.020
218	0.873 ± 0.040
220	0.923 ± 0.020
201	0.922 ± 0.004
200	0.850 ± 0.040
191	0.905 ± 0.012
189	0.828 ± 0.084
180	0.897 ± 0.035
179	0.951 ± 0.025
160	0.923 ± 0.007
155	0.859 ± 0.072
149	0.875 ± 0.014
134	0.890 ± 0.016
120	0.878 ± 0.007
114	0.843 ± 0.016

*Bulk populations; other sample numbers designate HMP550 S_1 lines.

TABLE 8. Riboflavin in Pearl Millet

Sample	μg/g
*RMP1(S)C1	2.18 ± 0.081
*HMP1700	2.52 ± 0.004
*Serere 3A	2.39 ± 0.112
*HMP550	2.79 ± 0.059
240	2.45 ± 0.011
220	2.64 ± 0.035
218	2.46 ± 0.049
201	2.42 ± 0.053
196	2.55 ± 0.047
193	2.49 ± 0.093
191	2.30 ± 0.178
189	2.10 ± 0.080
180	2.13 ± 0.049
179	2.35 ± 0.120
160	2.21 ± 0.067
155	2.35 ± 0.024
149	2.41 ± 0.005
134	2.30 ± 0.071
120	2.70 ± 0.071
114	2.36 ± 0.038

*Bulk populations; other sample numbers designate HMP550 S_1 lines.

CHARACTERIZATION OF PEARL MILLET PROTEINS

B. Mason and R. C. Hoseney

The classification of cereal proteins according to their solubility properties has helped scientists to understand why certain cultivars contain more nutritious protein. The protein solubility classes are known to differ in amino acid composition (Pomeranz, 1975). The alcohol soluble prolamines are generally deficient in lysine while the saline soluble and the alcohol insoluble protein classes are comparatively rich in this nutritionally critical amino acid. The amino acid composition of each solubility class has been found to be fairly uniform among the cereal species studied. The great nutritive gains achieved in breeding high lysine cultivars have resulted from depressing the synthesis of prolamines in the developing grain (Mertz, 1975). It is not known whether the proteins of pearl millet would follow a similar pattern. Such information would be valuable to pearl millet breeders and others seeking to improve the protein quality of this crop.

Work on the fractionation and characterization of pearl millet proteins will focus on the distribution of lysine among the different solubility classes. Current efforts are towards the identification of a protein fractionation procedure which adequately solubilizes pearl millet protein and yields consistent and distinct protein fractions. The modified Landry-Moureaux procedure of Robutti et al. (1974) has been found to satisfactorily solubilize the protein of flour ground from the HMP 550 bulk millet sample. The method will be evaluated for reproducibility with gel electrophoresis and ultracentrifugation techniques. Subsequently, additional pearl millet samples will be examined to investigate the relationship between protein solubility classes and amino acid composition in this crop. Grain protein from plants of different genotypes will be compared. In addition, a comparison will be made of grain protein from plants of similar genotypes but grown under diverse environmental conditions.

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CHARACTERIZATION OF PEARL MILLET STARCH

A. Beleia and E. Varriano-Marston

Starch comprises the major carbohydrate of pearl millet with the average content ranging from 60-65%. However, its properties have not been extensively studied. The work done on millet starch at Kansas State (Badi et al., 1976) resulted in the description of starch granule sizes, shapes, gelatinization range, and pasting properties of starch washed from one population of pearl millet. We are expanding this study to include water binding capacity (Metcalf and Giles, 1965), iodine affinities (Schoch, 1964), swelling and solubility patterns (Leach et al., 1959), amylose:amylopectin ratios (Montgomery and Senti, 1958), intrinsic viscosity (Greenwood, 1964) and susceptibility to enzyme attack. Sufficient lines or populations of millet will be used to estimate the genetic variability of those parameters.

RESULTS AND DISCUSSION

Early work showed that pearl millet flour exhibited a low amylograph peak viscosity. Current research (Table 9) suggests that there is considerable variability in peak viscosities among pearl millet populations. Studies are being conducted to determine if this variability is due to the starch physicochemical characteristics or to variability in alpha-amylase level; some of the results are presented below.

The cold water binding capacity of starches washed from the pearl millet populations varied from 85% (Serere 3A) to 99.5% (HMP 1700). The HMP 550 S_1 lines that were tested showed approximately the same water absorption: ∿87%.

Gelatinization temperature ranges did not differ greatly among populations; initiation temperatures averaged 58°C; birefringement end-point temperatures (BEPT) averaged 69°C. The BEPT for millet starch is slightly higher than that reported for wheat starch, but falls in the range reported for corn starch (Osman, 1967).

Solubility and swelling power tests give information concerning the behavior of millet starch during heating; some variability exists among populations (Table 10). For example, starch from the HMP 1700 population showed considerably lower swelling power and solubility at 95°C than the starch from the RMP 1 (S)CI population. These results may explain, in part, the lower amylograph peak viscosity obtained with the HMP 1700 flour (Table 9).

The iodine affinity values for the populations ranged from 4.43% to 4.75%. If 200 mg iodine/g is used as the binding limit for pure amylose, then the calculated amylose content would be 22.1% to 23.7%. These values would fall within the range reported for wheat starches (Medcalf and Gilles, 1965).

Experiments are being conducted to determine the amylose and amylopectin content of the various populations. The ratio of amylose to

amylopectin may be an important factor in the cooking and eating quality of millet, particularly if this grain is used as a rice substitute. In addition, intrinsic viscosities of the starch components will be determined because these values have been related to the cooking quality of other cereal grains.

The role of these starch physiocochemical characteristics in pearl millet eating quality will be more easily assessed once samples of "good" and "poor" quality millet (as judged by villagers in India and Africa) are received for analysis.

FUTURE WORK

Many food uses of pearl millet (e.g. asidah) involve allowing the grain to ferment overnight. Villagers who consume these products say that the fermentation step makes the grain sweeter. A perceived increase in sweetness suggests that there is a conversion of starch to sugars through the action of carbohydrates and that these enzymes are important in the quality of the end-products. Therefore, future work will concentrate on: (1) determining if there are significant differences in α-amylase activity among populations and cultivars of pearl millet, and (2) characterization of pearl millet α-amylase and determining the susceptibility of intact and solubilized millet starch to alpha-amylase attack.

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TABLE 9. PASTING CHARACTERISTICS OF PEARL MILLET FLOUR

Sample	Pasting Temp. °C	Peak Viscosity (B.U.)	Viscosity after 30 min at 95°C (B.U.)	Viscosity at 50°C (B.U.)
Whole meal				
RMPI(S)CI	75	240	200	400
HMP 1700	75	110	80	140
Serere 3A	75	165	140	300
HMP 550	75	90	70	140
Flour - 65% Extraction				
RMPI(S)CI	75	220	180	360
HMP 1700	75	65	60	120
Serere 3A	75	150	130	280
HMP 550	75	140	100	230
Bulk 1978	75	150	130	270

TABLE 10. SOLUBILITY AND SWELLING PATTERNS OF PEARL MILLET STARCHES

Temperature °C	Population							
	RMPI(S)CI		HMP 1700		Serere 3A		HMP 550	
	Solubility (%)	Swelling Power	Solubility (%)	Swelling Power	Solubility (%)	Swelling Power	Solubility (%)	Swelling Power
60	0.04	2.10	0.98	2.49	0.81	2.31	0.06	2.21
65	0.31	2.42	1.34	3.54	1.02	3.41	1.02	3.81
70	2.03	5.22	2.69	7.28	2.89	6.79	2.18	7.26
75	2.57	9.88	3.52	9.08	4.25	9.69	3.58	10.41
80	6.05	12.03	3.79	9.81	5.28	10.17	4.89	12.24
85	7.89	13.51	5.38	10.97	6.50	11.35	5.35	12.94
90	9.15	13.82	6.07	11.84	8.01	13.17	8.17	14.10
95	13.28	18.06	7.46	13.25	10.71	15.07	8.96	15.11

GRAIN QUALITY TESTS TO PREDICT END-USE PROPERTIES

A. de Francisco and R. C. Hoseney

Evaluation with various cereal grains has shown that the best measure of the functional quality of a grain is its ability to produce a product that is acceptable to the consumer. Since pearl millet is not a food crop in the U.S., it will be difficult for us to judge consumer acceptability. Therefore, our goal will be to develop simple tests that characterize the cooking characteristics of various cultivars. The relationship of these tests to consumer preference will be determined by analysis of "good" and "poor" functional quality pearl millet samples obtained from India and Africa. Steps have been taken to obtain an import permit for grain samples.

Work done on sorghum in India by Dr. M. vonOppen (ICRISAT economist) indicated that consumers showed preferences for certain cultivars. Evidence of the preference was the prices paid for certain cultivars. Preference implied that differences among cultivars were apparent. They also found that a number of parameters such as water uptake by the grain and grain hardness were related to consumer preferences for sorghum. Following their example, we are searching for simple tests (water absorption, hardness, alkali disintegration) to differentiate pearl millet cultivars. In addition, standardized tests for making chapaties and other products made from pearl millet are being developed. Our goal is to correlate biochemical properties with end-product characteristics.

ANIMAL FEEDING STUDIES

D. Dassenko and B. Fryer

The study of pearl millet quality requires an evaluation of the nutritional quality of the grain with respect to living biological systems. Therefore, animal feeding studies were conducted.

Biological availability of pearl millet protein was determined by feeding weanling rats for a 28-day period on 10% protein diets which were adequate in all other nutrients. The sources of protein in the diets were casein, raw whole wheat, raw millet, wheat chapaties, and millet chapaties.

Weight gain was linearly related to feed intake. When weight gain was adjusted for feed intake (Table 11), rats on casein diets were found to gain more weight than rats on any of the cereal diets. Of the cereal diets tested, rats gained more weight on raw millet than on raw wheat. However, cooking millet in the form of chapaties, resulted in a significant decrease in weight gain compared to the raw product.

The pattern of PER's was similar to that for weight gain (Table 11) Again, raw millet produced a higher PER than raw wheat, but the cooking process significantly lowered the PER for millet.

Digestibility of protein and calories also varied with the diet. Protein was much more available from the casein diet than from the cereal diets; calories were equally digestible from casein and cereal diets. Raw millet, wheat chapaties and millet chapaties showed essentially the same protein digestibility; lower values were obtained with raw wheat. On the other hand, cooking made the millet protein less available and the wheat protein more available.

The next phase of the nutritional study will be concerned with the effect of fermentation and cooking on the nutritional value of 68% and 100% extraction millet flour. Three diets each will be run with the two extracted flours: (a) raw, (b) fermented and cooked product similar to asidah, and (c) nonfermented and cooked product similar to tuwo. The resulting products will be evaluated for thiamin, riboflavin, niacin and minerals (Na, K, Ca, Mg, Fe) before being mixed into diets and fed to rats to determine protein bioavailability.

TABLE 11. PROTEIN EFFICIENCY RATIOS, PROTEIN DIGESTIBILITY AND CALORIE DIGESTIBILITY OF FIVE DIETS FED TO WEANLING RATS FOR 28-DAY PERIOD.

Diet	Weight gain[1] (gm)	PER	Coefficient of Protein Digestibility[2]	Coefficient of Calorie Digestibility[3]
Casein	63.46[a]	2.734[a]	93.6[a]	93.6[a]
Raw whole wheat flour	43.03[b]	1.323[b]	82.4[b]	91.5[b]
Raw pearl millet	49.99[c]	1.434[c]	90.5[c]	94.3[a]
Wheat Chapaties	49.37[c]	1.418[c]	89.3[c]	92.2[b]
Millet Chapaties	43.36[b]	1.176[d]	88.6[c]	93.4[ab]

[1] Weight gain was adjusted for feed intake. Those numbers not superscripted by the same small letter are significantly different at the 0.05 level.

[2] $$\frac{N_{food} - N_{feces}}{N_{food}} \times 100 = \text{Protein Digestibility}$$

[3] $$\frac{KCal_{feed} - KCal_{feces}}{KCal_{feed}} \times 100 = \text{Calorie Digestibility}$$

Objective 4: "Determine the storage stability of pearl millet grain and millet meal by determining the factors contributing to grain losses during storage and determining the factors contributing to the development of rancidity in millet meal."

CHARACTERIZATION OF LIPIDS IN PEARL MILLET

C. Lai and E. Varriano-Marston

Personal communications with Dr. Geervani (Dean, Home Science College, Hyderabad, India) and others indicated that pearl millet quickly becomes rancid once it has been ground into a meal. It is well known that lipids are associated with rancidity. Therefore, an investigation into the lipids (content and types) of pearl millet cultivars was initiated as the first step in understanding the factors responsible for the poor storage stability of millet meal.

METHODS

Free and bound lipids were extracted from four populations of pearl millet and 18 HMP 550 S_1 lines. Free lipids were extracted from the ground meal with petroleum ether in a Goldfish Apparatus; bound lipids were extracted by the method of Chung (1973).

The free and bound lipid fractions were characterized by TLC on silica gel using chloroform: methanol: water (65:25:4, by vol) to separate polar lipids and chloroform to separate nonpolar lipids. Lipids were tentatively identified by co-chromatography with known lipid compounds, by comparison of relative R_f values, and by the use of specific sprays.

Fatty acids were determined by gas chromatography of their methyl esters on a 6 foot column packed with 10% SP-2330 on 100/120 Chromosorb W AW (Supelco).

RESULTS

The percent free and bound lipids in pearl millet samples are presented in Table 12. Free lipid content ranged from 5.87% to 7.08%; bound lipids ranged from 0.57% to 0.90%. These values are in agreement with those reported in the literature (Rooney, 1978).

Nonpolar lipid components tentatively identified by TLC were: sterol esters, triglycerides, diglycerides, free fatty acids, and partial glycerides. Triglycerides were the major nonpolar component.

The S_1 line samples were similar to the bulk samples in the level of both free and bound nonpolar lipids. In addition, the nonpolar lipid components of the bound and free lipid fractions were similar.

The polar bound lipids were tentatively identified as monogalactosyl glycerides, phosphatidyl choline and lysolecithin. On the other hand, neutral lipids were the only componets identified in the free polar lipids.

Work is currently underway to quantitate the fatty acid components of pearl millet cultivars by gas chromatography. The major fatty acids have been tentatively identified as palmitic acid, stearic acid, oleic acid, linoleic acid, and arachidic acid.

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TABLE 12. Free and Bound Lipids of Pearl Millet Cultivars

Sample	Free lipid (%)	Bound lipid (%)
*RMPI(S)CI	6.80	0.90
*HMP1700	6.92	0.82
*Serere 3A	6.20	0.58
*HMP550	7.08	0.74
HMP550 S_1 LINES		
114	6.33	0.88
120	6.21	0.77
149	6.40	0.77
155	6.46	0.73
160	6.14	0.75
179	6.50	0.75
180	6.32	0.74
189	5.87	0.76
191	6.19	0.78
193	6.07	0.64
196	5.66	0.57
200	5.88	0.70
201	5.95	0.73
218	6.03	0.68

*Bulk populations

PEARL MILLET: QUALITY DETERIORATION DURING STORAGE

C. Lai

The HMP 550 bulk population of pearl millet was ground and the whole meal stored in cotton bags under the following storage conditions: 19°C, 58% R.H.; 27°C, 64% R.H.; and 42°C, 75% R.H. After designated storage periods, the following tests were conducted: (a) titratable acidity, determined by the AOAC (1960) method; (b) moisture content and mold counts, AACC (1962) methods; and (c) organoleptic (sniff) tests using a trained panel.

Th total titratable acidity (TTA) and moisture content of millet meal stored at 42°C, 75% R.H. increased rapidly during the first 108 hr of storage compared to millet meal stored at 27°C, 64% R.H. or 19°C, 58% R.H. (Figure 1). In addition, organoleptic evaluation of stored millet meal indicated that high temperatures and humidities resulted in a decrease in the time necessary for detection of off-odors by the panelists (Table 13). The results of the subjective and objective evaluation of rancidity indicate that the threshold for detection of off-odors by the panelists is around 30 mg KOH per 100 g flour. Organoleptic evaluation appears to be a more sensitive measure of deteriorative changes during storage than determination of TTA.

The increase in TTA and off-odors during the storage of millet meal could be a result of hydrolysis of lipids by lipase or by the action of proteases on proteins. Identification of lipids extracted from stored samples by TLC and gas chromatography will help to determine what role lipids play in this process. Peroxide values will also be measured on stored samples to determine how oxidative changes correlate with millet deterioration.

Because mold growth can contribute to lipid degradation via fungal lipase, the degree of mold attack (initial mold counts) and the specific species involved were determined for HMP 550 pearl millet bulk sample (Table 14). The sample was found to contain normal levels of field fungi typically found on cereal grains grown in Kansas.

Figure 1

Effect of Storage Condition on the Moisture Content and Titratable Acidity of Whole Millet Flour

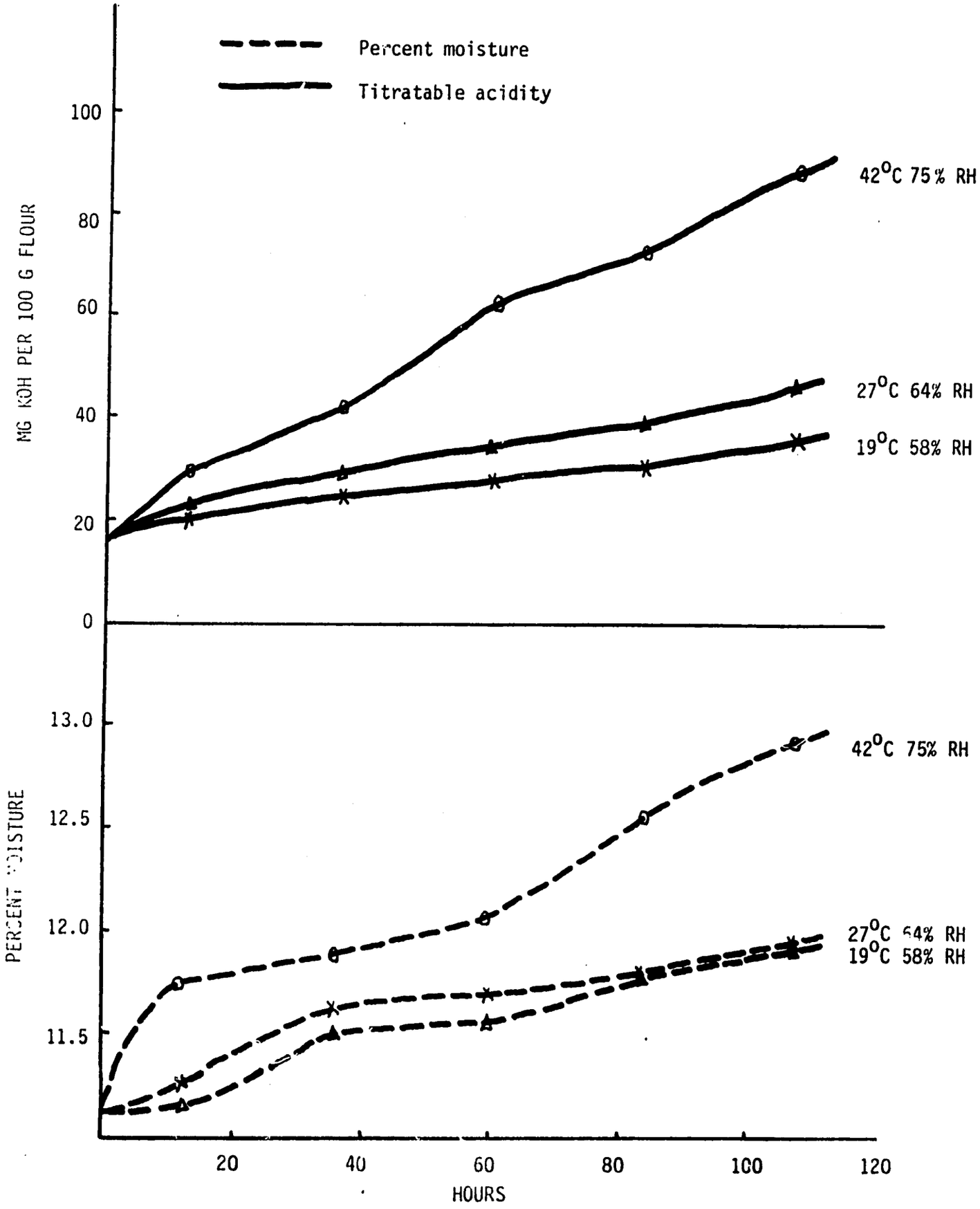

TABLE 13

PERIOD AFTER STORAGE THAT CHANGE IN ODOR CAN BE DETECTED BY PANEL

TIME INTERVAL	STORAGE CONDITION		
	19°C 58% RH	27°C 62% RH	42°C 70% RH
HOURS	108	60	12

FIELD FUNGI IN PEARL MILLET

R. Burroughs

The field fungi invading pearl millet at harvest were determined by plating 100 surface-disinfected kernels (1 minute wash in 2% sodium hypochlorite (Chlorox), 2 sterile distilled water rinses) on malt agar containing 4% sodium chloride and 200 ppm Tergitol NPX. Fungi were identified after 6-7 days incubation at room temperature. Alternaria was the predominant fungus with a much smaller percentage of kernels invaded by Fusarium and Cladosporium (Table 14). Also identified on millet kernels were the genera Curvularia, Helminthosporium, Penicillium, Phoma and Rhizopus. The principal field fungi found are of the same genera, and approximately the same percentages, as found in grain sorghum grown in Kansas.

Ergosterol content indicates the extent of total fungal invasion in grain because viable and non-viable fungal biomass is measured. However, the determination gives no indication of the specific fungi involved. The ergosterol assay measures the extent of in-field weathering which seed plating cannot do. Ergosterol values generally correlate with visual ratings on appearance of grain and are higher in grain samples with high Fusarium counts. Fusarium invades and rots seeds while other field fungi are largely confined to the pericarp. In the Kansas grown millets, ergosterol ranged from 1.5-14.9 μg/g (Table 14). Only three of the 16 lots tested had ergosterol contents over 3.7 μg/g. Values determined for pearl millet are comparable with those reported for grain sorghum (Seitz, et al.). A group of commercial sorghum hybrids had 1.9-3.3 μg/g ergosterol at harvest in 1976. A discolored, weathered sample had 13.5 μg/g ergosterol.

L. M. Seitz, H. E. Mohr, R. Burroughs, and D. B. Sauer. 1977. Ergosterol as an indicator of fungal invasion in grains. Cereal Chem. 54:1207-1217.

Table 14. Percentage invasion by principal field fungi and ergosterol content in pearl millet (selected HMP550 C_1S_1 progeny), 1977 crop [a]

1977 Series No.	Percent kernels invaded by Alternaria	Fusarium	Cladosporium	No fungi	Ergostero µg/g
114	67	11	2	21	
120	69	38	3	6	14.9
134	54	9	3	29	2.3
149	66	11	2	20	5.8
155	80	23	0	5	6.0
160	90	22	2	8	3.3
179	68	22	0	15	3.6
180	74	12	0	23	1.9
189	57	12	3	30	3.5
191	64	9	1	39	2.6
193	48	9	3	39	3.0
196	59	9	0	36	3.3
200	72	10	1	14	3.7
201	61	7	1	33	2.2
218	57	3	3	38	1.5
220	73	2	1	23	1.8
240	54	10	0	40	2.5
550[b]	65	14	6	22	

[a] Millet stored at 4C; examined for fungi May, 1978.

[b] Bulked sample; examined October, 1978.

Ergosterol analyses performed at USGMRL by L.M. Seitz.

INITIAL SCREENING OF PEARL MILLET TO DETERMINE INSECT SUSCEPTIBILITY

D. Kossou and J. Pedersen

Using a bulk population of pearl millet grown in Kansas (HMP-550), an initial screening was conducted to determine if millet was more or less susceptible to infestation by certain species of stored-product insects. Information of this type is currently not available in the literature.

Fifteen of the major insect pests species which attack cereal grains were used in an initial "no-choice" screening test. Twenty-five gram samples of millet at 13.5 ± 0.25% moisture content (m.c.) were infested with either 30 adult, 30 newly emerged larvae, or 50 eggs, depending on species of insect. Infested millet samples were stored in small glass jars with screened lids in a rearing room maintained at 27 ± 1°C and 65 ± 3% RH for a period of 6 or 8 weeks. At the end of the exposure period each sample (Table 15) was examined for number of insects, loss of seed weight, and weight of frass (excrement, dust, etc.).

Rice and maize weevils produced the greatest numbers of insects per 25 gram sample (22 and 19 fold increases, respectively) and were responsible for the greatest weight loss (44 and 43% loss, respectively) in the samples. Granary weevils, lesser grain borers, sawtoothed grain beetles and cigarette beetles had 5-6 fold increases in their populations and were responsible for from 5 to 18% weight loss. Although the red flour beetle had only a 4 fold increase in numbers, it caused over 9% weight loss.

The potential for population increase and the degree of damage and loss produced by the various species will be used to select test insects for future studies. It is anticipated that initially at least 12 different varieties of millet will be studied to determine the degree of insect damage caused by various species of insects. Damage will be determined both in millet stored on the head and in threshed millet.

Because the Angoumois grain moth is a common pest of millet in Africa, its biology is being studied in millet, as compared with that in sorghum, wheat and corn. Factors studied include: success of development in individual kernels, developmental period, longevity, fecundity, size of eggs, and sex ratio. Loss of weight in millet, sorghum, wheat and corn as a result of development of a single moth are given in Table 16.

TABLE 15. NUMBER OF INSECTS, LOSS IN SEED WEIGHT AND AMOUNT OF FRASS PRODUCED IN 25 GRAMS OF MILLET (HMP-550) AT 13.5% m.c. (80° + 1°F., 65 ± 3% RH) AFTER 6 WEEKS

INSECTS[1/2/]	NUMBER			SEED WEIGHT LOSS		FRASS WEIGHT	
	ADULTS	LARVAE	PUPAE	GRAMS	%	GRAMS	%
Rice Weevil (Kansas Strain)	658	-	-	11.073	44.3	0.762	3.0
Maize Weevil (Arkansas Strain)	562	-	-	10.742	43.0	1.346	5.4
Granary Weevil	141	-	-	4.694	18.8	0.551	2.2
Lesser Grain Borer	155	-	-	3.517	14.1	2.093	8.4
Red Flour Beetle	41	51	34	2.340	9.4	1.622	6.5
Confused Flour Beetle	35	21	0	0.795	3.2	0.568	2.3
Sawtoothed Grain Beetle	134	17	15	1.252	5.0	0.519	2.1
Merchant Grain Beetle	77	10	19	1.032	4.1	0.509	2.0
Flat Grain Beetle	35	5	5	0.952	3.8	0.481	1.9
Rusty Grain Beetle	31	27	0	0.800	3.2	0.383	1.5
Cigarette Beetle	192	-	-	2.608	10.4	1.839	7.4
Drugstore Beetle	45	-	-	1.202	4.8	0.965	3.9
Warehouse Beetle[3/]	0	30	-	1.088	4.4	0.920	3.4
Angoumois Grain Moth[4/]	21	6	0	1.240	5.0	0.420	1.7
Indian-Meal Moth[4/]	1	7	0	0.820	3.3	0.530	2.1

[1/] Scientific names of insect shown in Appendix

[2/] All samples infested with 30 adult insects per sample for 6 weeks except as noted.

[3/] Sample infested with 30 newly emerged larvae.

[4/] Samples infested with 50 eggs each for 8 weeks.

TABLE 16. WEIGHT LOSSES (mg) OF INDIVIDUAL KERNELS OF MILLET, SORCHUM, WHEAT AND CORN CAUSED BY DEVELOPMENT OF SINGLE ANGOUMOIS GRAIN MOTHS AND THE WEIGHT OF NEWLY-EMERGED MOTHS

MOTH	MEAN INITIAL WT. OF KERNEL (mg)	WEIGHT LOSS/KERNEL (mg) MEAN	RANGE	MEAN% WT. LOSS/KERNEL	WET WEIGHT OF MOTH (mg) MEAN	RANGE
	Millet					
♂	13.87 (22)*	11.19	8.10-14.70	80.68	2.97	1.05-6.20
♀	13.55 (22)	12.80	8.60-16.55	94.46	2.89	1.15-6.50
	Sorghum					
♂	36.01 (32)	16.55	10.25-25.55	45.96	3.22	1.10-6.30
♀	35.36 (29)	17.92	10.20-26.55	50.68	4.04	1.50-6.65
	Wheat					
♂	38.47 (40)	14.45	7.00-24.55	37.55	2.99	1.50-4.95
♀	36.90 (36)	18.20	13.85-27.90	49.32	4.21	2.85-6.55
	Corn					
♂	321.49 (31)	24.00	16.60-35.40	7.47	3.78	2.30-7.70
♀	305.27 (22)	35.01	18.90-48.80	11.47	5.81	3.80-7.90

* Number of individuals

APPENDIX 1. COMMON AND SCIENTIFIC NAMES OF INSECTS

Rice Weevil	*Sitophilus oryzae* (L.)
Maize Weevil	*S. zeamais* Mots.
Granary Weevil	*S. granarius* (L.)
Lesser Grain Borer	*Rhizopertha dominica* (F.)
Red Flour Beetle	*Tribolium castaneum* (Hbst.)
Confused Flour Beetle	*T. confusum* DuVal.
Sawtoothed Grain Beetle	*Oryzaephilus surinamensis* (L.)
Merchant Grain Beetle	*O. mercator* (Fanv.)
Flat Grain Beetle	*Cryptolestes pusillus* (Schonh.)
Rusty Grain Beetle	*C. ferrugineus* (Steph.)
Cigarette Beetle	*Lasioderma serricorne* (F.)
Drugstore Beetle	*Stegobium paniceum* (L.)
Warehouse Beetle	*Trogoderma variabile*
Angoumois Grain Moth	*Sitotroga cerealella* (Oln.)
Indian-Meal Moth	*Plodia interpunctella* (Hbn.)

VII. Financial status of the project at the end of the first fiscal year, 1 October 1977 - 30 September 1978.

	AID - 3 yr funded	KSU Budget first year	Actual Expenditure
Salaries	290,170.00	89,260.00	54,797.59
Fringe Benefits	43,124.00	12,532.00	3,955.13
Indirect Costs	187,766.00	57,309.00	33,102.74
Travel & Per Diem	72,000.00	20,000.00	17,426.60
Equipment	51,000.00	51,000.00	37,040.90
Material & Supplies	100,246.00	25,246.00	10,117.47
Other Direct Costs	15,694.00	4,500.00	4,442.53
Publications	10,000.00	2,000.00	69.13
Grand Total	$770,000.00	$261,847.00	$160,952.04